Ernest MERCIER
Adm. délég. de l'UNION d'ÉLECTRICITÉ

Translated by C. M. POPP
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THE "UNION D'ÉLECTRICITÉ"

and the

GENNEVILLIERS STATION

ÉDITÉ PAR LA
REVUE INDUSTRIELLE
57, RUE PIERRE-CHARRON
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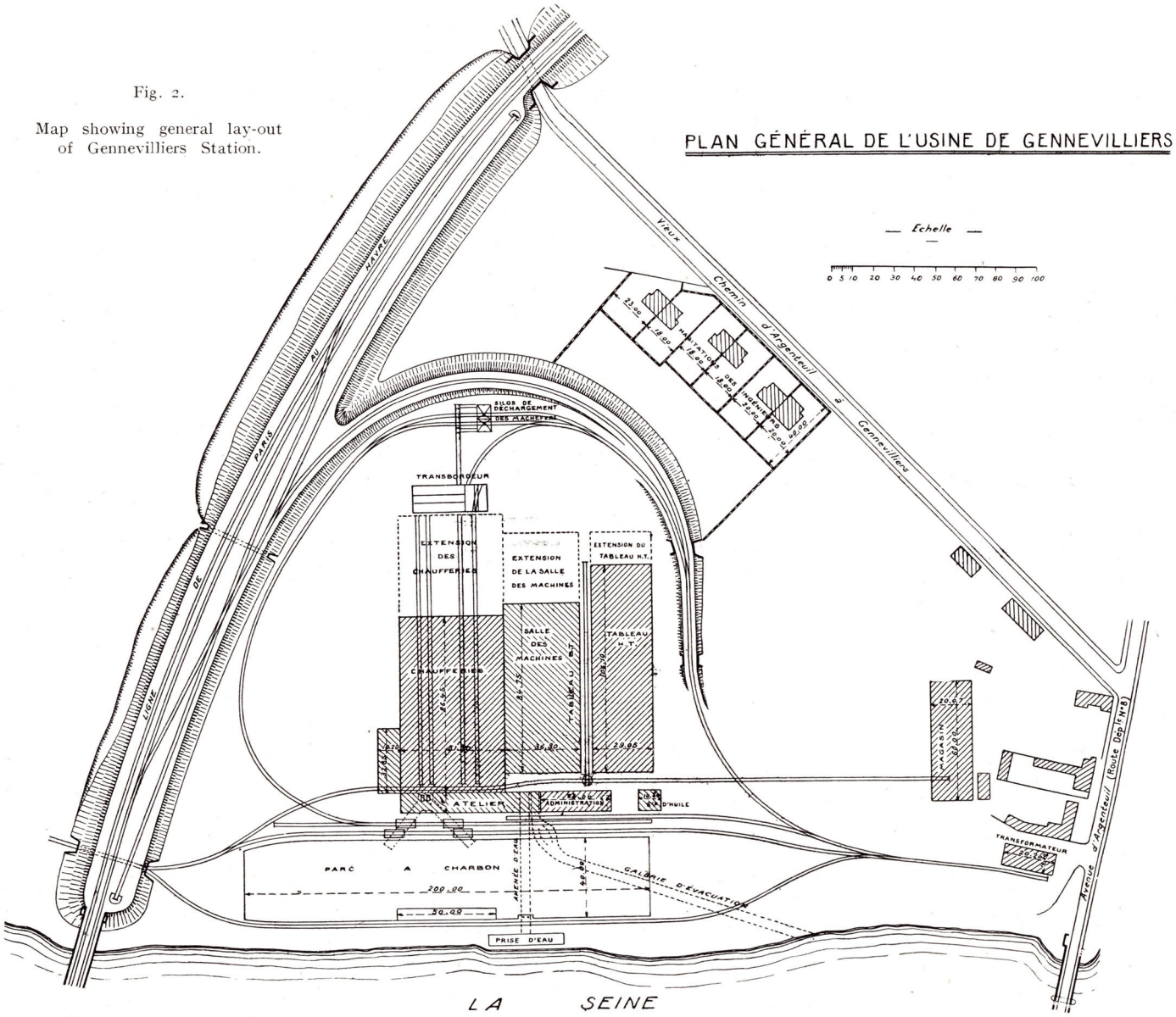
Fig. 1. — The Gennevilliers Station (View taken from the Seine, May 1922).

Fig. 2.

Map showing general lay-out of Gennevilliers Station.



CHAPTER I

Particularities

I. ELECTRICITY IN THE PARIS DISTRICT AFTER THE WAR

The electrical plants have done their duty during the War.

Under the fire of the enemy, Paris was transformed into an immense armament factory, new shops were installed in all parts of the city, those already existing were enlarged, and intensive day and night work was organized by every factory. This great effort would have been a failure if every factory had been obliged to produce its own power : a prodigious waste of fuel would have occurred ; the distribution of coal, the control of its consumption would have become impracticable.

The electrical engineers can be legitimately proud of the fact that, during this tragic period, the production was not impeded by the lack of necessary power.

When put face to face with duties nearly doubled, when repairs brought forth problems almost unsolvable, when the installation of spare machines was nearly an impossibility, and when labour was almost unobtainable, the problems solved were almost unbelievable.

The absolute devotedness of all, — managers, engineers in the generating and distributing stations, foremen, workmen, — alone permitted the meeting of all requirements. It must be added that they constantly received from manufacturers — their clients — the greatest cooperation and good-will which never failed, even under restrictions and regulations, indispensable it is true, but nevertheless severe.

The War, in illustrating the advantages of the adaptability and economy of electric distributing stations, added to the cause of the central stations the major part of industrials who had remained dissident up to that time, but, on the other hand, it also brought to light all the numerous imperfections of the present organization of the distributing systems, which were started at a time when the electrical industry itself was still in its infancy. These systems were developed at a time when ideas were not yet settled and where each one, in trying to do his best, worked on a different basis than his neighbour, and have progressed each one along the lines upon which they started. It was thus that single-phase, two-phase and three-phase systems of 25, 42, 50 and 53 periods grew up side by side, incapable of helping one another and imposing on their customers an infinite variety of apparatus. On the other hand, the exceptional effort accomplished and maintained continuously during four years, regardless of the fact they had been victoriously supported both by personal and material, had none the less imposed on the latter a great deal of wear and when Peace came, the central stations found themselves in a very critical position, as the electrical companies were not able, as certain others had, to secure a sufficient remuneration for their efforts. This does not intend to diminish the merit of the distributing companies but to recognize here the obligatory disinterestedness of their efforts.

Under such conditions, and considering the unheard-of increase of prices which have followed the War, the work of the Companies who had to put their equipment into working order, and, in many instances, their finance, has not been of the easiest.

Already during the War, these circumstances were foreseen by the Administration of the Ministry of Armaments and by the Ministry of Public Works. With a perspective, which must be praised, the Ministry of Public Works has, since 1918, undertaken the study of a national program for the organization of the distributing systems and central stations. At that time, the frequency of 50 cycles was adopted as the standard frequency

for the whole country. At a later date, a project was prepared to organize a superpower system under State control, comprising a large net work connecting the principal stations, covering the entire country.

Such were, briefly resumed, the circumstances and the general ideas at the beginning of 1919, and at the time when an industrial group constituted, under the name of the « Union Française d'Electricité », a technical company having in view the reorganization of the distributing systems in the Paris district.

The existing installations were at the time the following :

Compagnie Parisienne de distribution d'électricité (C. P. D. E.)	Generating Stations ...	Saint-Ouen (Usine Nord), 80 000 kw installed. Issy-les-Moulineaux (Usine Sud), 40 000 kw installed.
	District.....	City of Paris. Municipal concession, plants and lines property of the City of Paris.
	Distribution....	Two-phase, 41,66 cycles, 12 500 volt and also direct current.
Société d'Electricité de Paris	Generating St..	Saint-Denis, 75 000 kw installed.
	District.....	Chemin de Fer Métropolitain (subway) (in part). Chemin de Fer Nord-Sud (subway) (in part). Compagnies de Traction (street-cars) (in part). Supply of lighting and power in parts of Northern suburbs of Paris. Supply of peak and emergency power to the C. P. D. E.
	Distribution....	*a*) traction ..... 3-phase. 25 cycles. 10 500 volts. *b*) other ..... Two-phase. 41,66 cycles. 12 500 volts.
Société le Triphasé Nord-Lumière	Generating St..	Asnières, 46 000 kw installed.
	District.....	Various sections of the North and North-West suburbs of Paris. Compagnies de Traction (in part). Supply of peak and emergency power to the C. P. D. E.
	Distribution....	*a* 3-phase. 25 cycles. 6 500 volts. *b* Two-Phase. 41,66 cycles. 12 500 volts.
Société de l'Ouest-Parisien Ouest-Lumière	Generating St..	Puteaux, 45 000 kw installed.
	District.....	Part of the Northern Suburbs of Paris. Compagnies de Traction (in part).
	Distribution....	Two-Phase and 3-Phase. 53 cycles. 10 000 volts.

Compagnie du Secteur électrique de la rive gauche de Paris	Generating St..	Issy-les-Moulineaux, 8 000 kw installed.
	District.....	Various concessions in Paris suburbs.
	Distribution....	Two-Phase. 50 cycles. 15 500 volts.
Compagnie Générale de Distribution d'énergie électrique	Generating Stations...	Vitry, 36 000 kw installed. Billancourt (under construction) 22 000 kw installed.
	District.....	Compagnies de Traction (in part). Chemin de Fer Nord-Sud (subway). Distributing Lines of the Sud-Lumière and various industrial customers.
	Distribution....	3-phase. 25 cycles. 13 500 volts.
Energie électrique de la Région parisienne	Generating Stations...	Nanterre, 20 000 kw installed. Issy-les-Moulineaux (under construction) 31 000 kw installed.
	District.....	Chemins de Fer de l'Etat.
	Distribution....	3-phase. 25 cycles. 5 500 volts.
Société de l'Est-Parisien Est-Lumière	Generating St..	Alfortville, 23 000 kw installed.
	District.....	East suburbs of Paris.
	Distribution....	3-phase. 50 cycles. 5 500 volts.

To this lengthy list, must be added the Municipal disposal plants, managed by Sociétés Fermières.

La Société des Engrais complets	Generating Stations....	Saint-Ouen. Issy-les-Moulineaux. 3-phase. 50 cycles.
La Société Fermière de la Voirie de Paris	Generating Stations....	Romainville. Ivry. 3-phase. 50 cycles.

District of both Municipal disposal plants :

The refuse disposal plants supply, either wholly, or with the aid of the distributing systems, certain municipal services, particularly the drainage and sewerage installations, and distribution of water.

II. PROGRAM OF THE "UNION D'ÉLECTRICITÉ" AND ITS EXECUTION

The Technical Company the « Union Française d'Electricité » has laid the basis of a large program of which the leading were the following :

a) To join together the various distributing companies, and to establish large generating stations producing power under the best conditions.

b) To standardize distribution, leaning towards the adoption of standard 3-phase, 50 cycle current.

c) To relieve the distributing companies from the necessity of keeping up and enlarging their generating plants and to permit them to devote all their activities to the development of distribution.

d) To prepare in the future for the use of hydro-electric power.

This program could not but interest indirectly the Compagnie Parisienne de Distribution Electrique on account of its municipal character and the Société d'Electricité de Paris because of its special customers; the same applies to the municipal disposal plants.

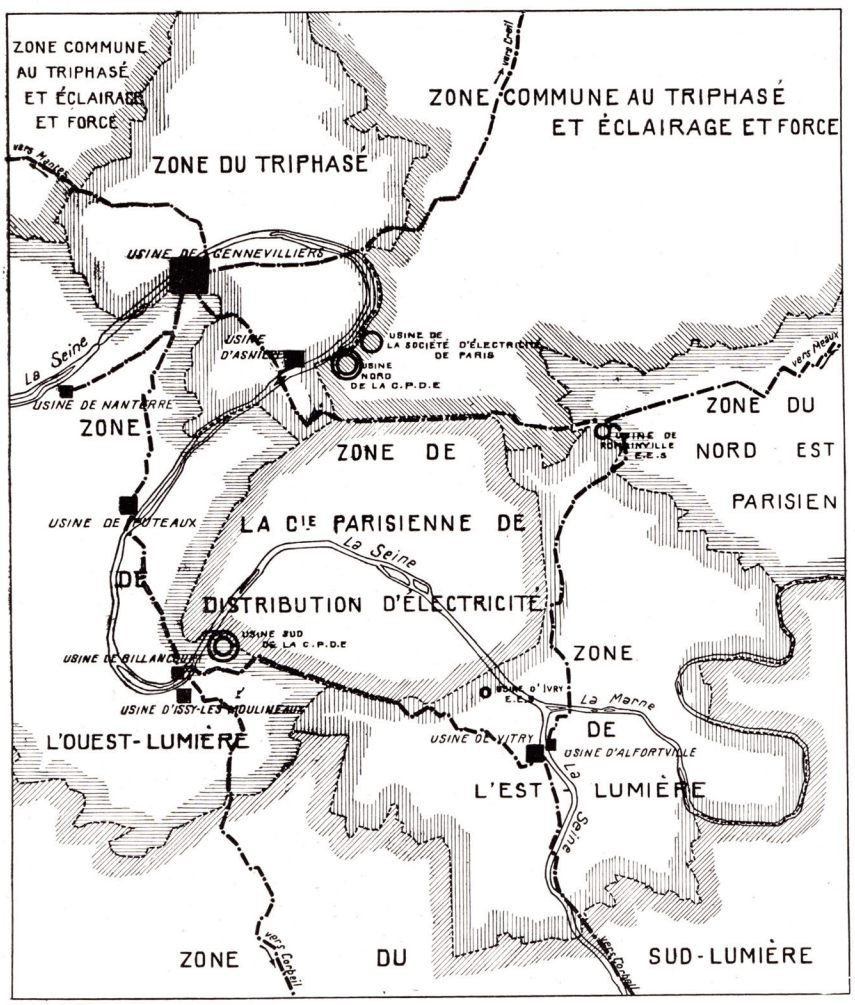


Fig. 3. — Map of the Paris Region, showing :
a) The zones of the various distributing companies (limits indicated by shaded lines).
b) The principal electrical plants (Those appartaining to the Union d'Electricité by squares, the others by circles).
c) The 60 000 volt distribution lines of the Union d'Electricité (by broken lines _.._.).

With an extremely clear and practical prospect for the future, all of the other Companies have agreed to adhere to this program and to participate in its success, and thereafter the progress has been rapid.

Created in March 1919, the Union Française d'Electricité united, during the following Summer, with the Compagnie Générale de Distribution d'Energie Electrique, and took the name of Union d'Electricité.

Soon after, the Union d'Electricité absorbed the Energie Electrique de la Région Parisienne.

Before the end of the same year, the Union had made definite agreements with the following Companies : The Triphasé, the Ouest-Lumière, the Secteur de la Rive Gauche, l'Est-Lumière and acquired the ownership of the generating plants of these various Companies.

At the same time, the Union d'Electricité finished

making its plans for the Gennevilliers power station and placed the first orders for the material.

The construction started in the Spring of 1920, but practically stopped by a strike, was again taken up in the beginning of the Summer.

Eighteen months later the first unit was under test.

In the meanwhile, the construction of the Billancourt station and also of Issy-les-Moulineaux was completed. The program of work already undertaken in the generating stations, which had been purchased or absorbed, was also completed, so that more than 100 000 kw of turbo-alternators, entirely modern and in good working condition, were put in operation in these various factories.

These undertakings had been continued regardless of the construction of the Gennevilliers station in order to meet the increased requirements. Simultaneously, all of the old material was put in good condition and these measures produced a very satisfactory increase in efficiency of the various generating stations.

III. DISTRIBUTING LINES

The distributing systems of the Union, which are under construction, will be fed by the following stations :

the new station at Gennevilliers (200 000 kw) installed at the start ;

the station of Vitry, installed as a stand-by plant, (48 000 kw actually installed and eventually 80 000) ;

the two stations of Nanterre and Issy-les-Moulineaux, which the State has the right to repurchase ;

the hydro-electric station of Eguzon, located on the river Creuse and now under construction (40 000 kw) ;

eventually, the hydro-electric stations in the center of France or on the Rhône, which are proposed or in course of construction ;

the four stations, Alfortville, Asnières, Billancourt and Puteaux, having a total installed capacity of 152 000 kw (of which 55 000 kw is being produced by machinery built after the Armistice). These stations will be put out of service consecutively as the various units of 40 000 kw at Gennevilliers are installed and put into operation.

The material, buildings and grounds of these stations must be sold. This operation, facilitated by the excellent condition of the material, has been already prepared by a special department organized for this service (1).

The distributing station on the « Secteur électrique de la Rive Gauche de Paris », was the first to be discontinued and has been entirely disposed of under the best possible conditions.

DISTRIBUTING SYSTEM

The problem, to be solved, involved the transmission to a limited number of points (old stations) of rather large blocks of power, varying according to the individual case from 10 000 to 40 000 kw. As the distribution net work spreads approximately 50 kilometers around Paris, it was necessary to transmit at high tension.

At the same time, due to part of the district being closely built, it was impossible to contemplate the use of overhead transmission lines except in the outlying districts. In consequence thereof, the Union had to adopt the highest tension which can be practically transmitted with absolute security by underground cables.

The tension selected was that of 60 000 volts.

(1) « Service Spécial des Ventes » de l'Union d'Electricité, 57, rue Pierre-Charron, Paris (8e).

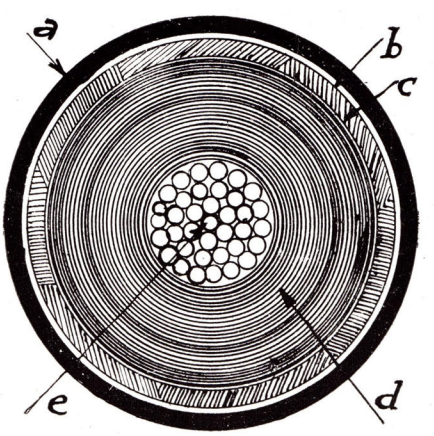


Fig. 4. — Cross section view of single-conductor, 60 000 volt cable (exact size).

a) Asphaltum treated cord.
b) Tarred cloth.
c) Lead cover.
d) Insulation.
e) Stranded Conductor.

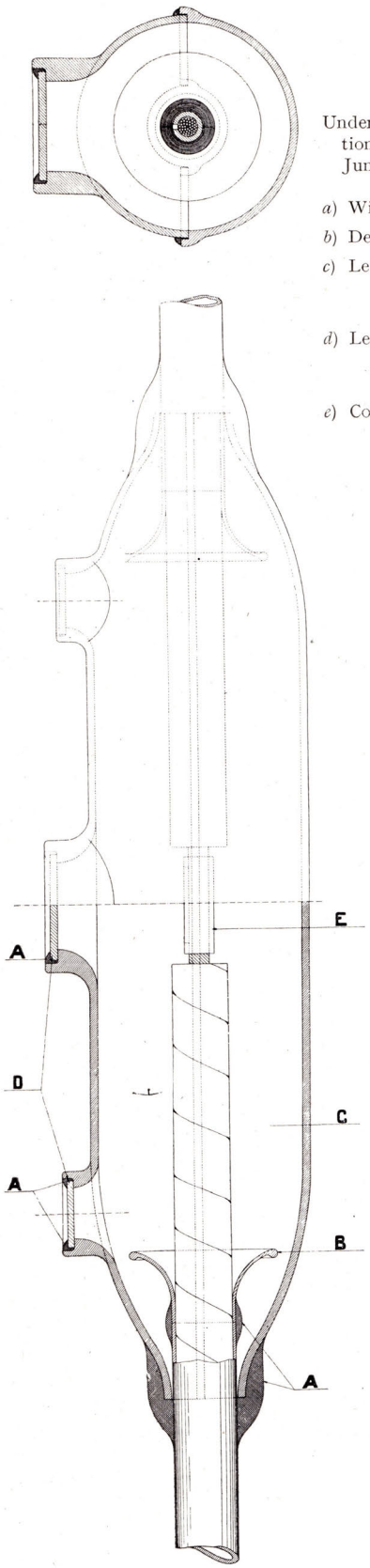


Fig. 5.

Underground distribution at 60 000 volts. Junction box.

a) Wiped joints.

b) Deflector.

c) Lead case filled with insulating material.

d) Lead washers for closing filling vents.

e) Connector.

All necessary measures were taken, however, to reduce this voltage to 50 000 should the necessity occur.

At first, this figure seemed to be very high to engineers of all countries. It was only after a minute and methodical study, carried on continuously during two years, that this figure was finally adopted. The use of three conductor cables was abandoned after some very interesting tests, as it did not allow a high enough factor of safety, and furthermore it would have cost considerably more than the system adopted. There was therefore chosen, as a last consideration, single-conductor cables operated in group of three constituting the three phase lines. As is known, the principal advantage of single-conductor cables for the three phase transmission is that the insulation is subject only to the dielectric stress of voltage to neutral and not to voltage between lines.

The voltage to neutral is $\frac{60\,000}{\sqrt{3}} = 35\,000$ volts, approximately, and therefore the cables are as easy to install as 35 000 volt cables, of which thousands of kilometers are in service.

The grouping of the cables was made the subject of another long investigation and the usual arrangement of placing the cables side by side in same plane with a fourth cable, used as spare, was not found satisfactory and the three cables of each line were grouped in a triangle with their shells in contact imitating a three-conductor cable.

Special arrangements were studied to facilitate the installation and to ensure proper cable protection and the continuity of the lead covers as well as their grounding at certain places.

Few questions have necessitated so much research and difficult studies, and the result has been to secure for underground lines a remarkably high factor of security.

The neutral point of the distribution system is solidly grounded.

The protection of the entire main distribution is provided by the Merz-Price system, the pilot wires being grouped into multi-conductor cables. These relays, in case of a cable failure, will open simultaneously the automatic circuit breakers located at each end of the faulty section of cable. The pilot cables also include telephone circuits which permit

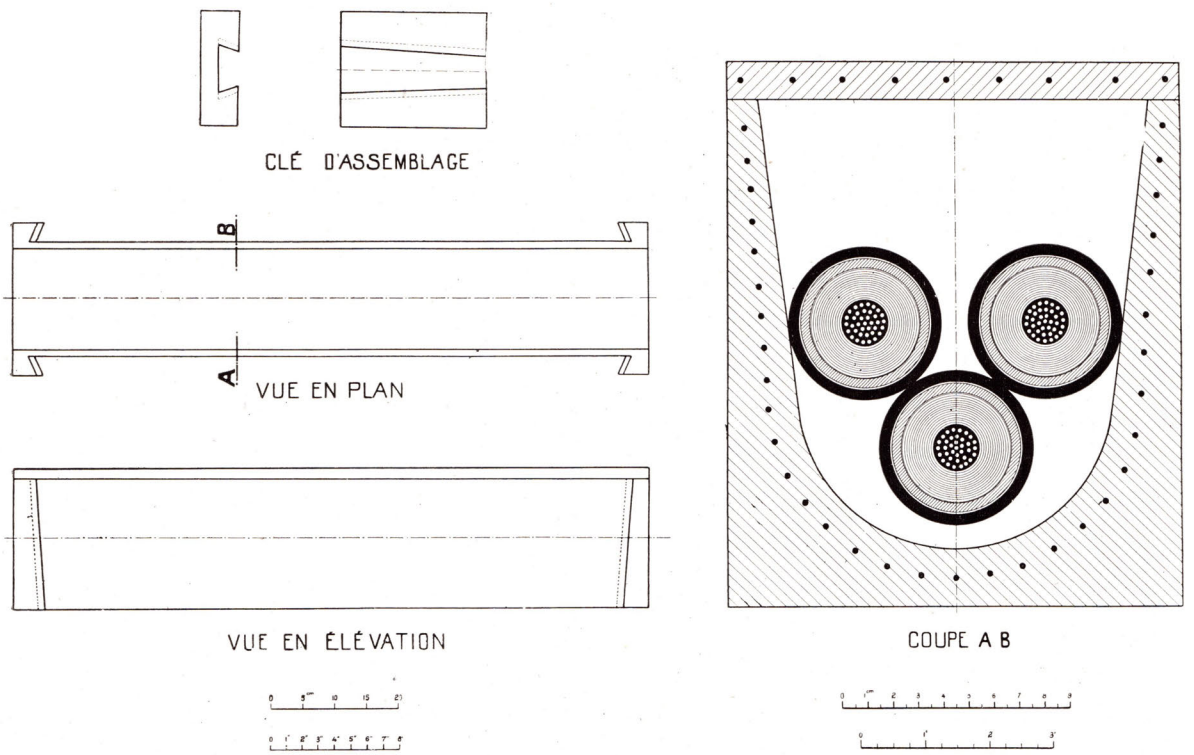


Fig. 6. — Locking key ; Plan view ; Side elevation ; Section A.-B.

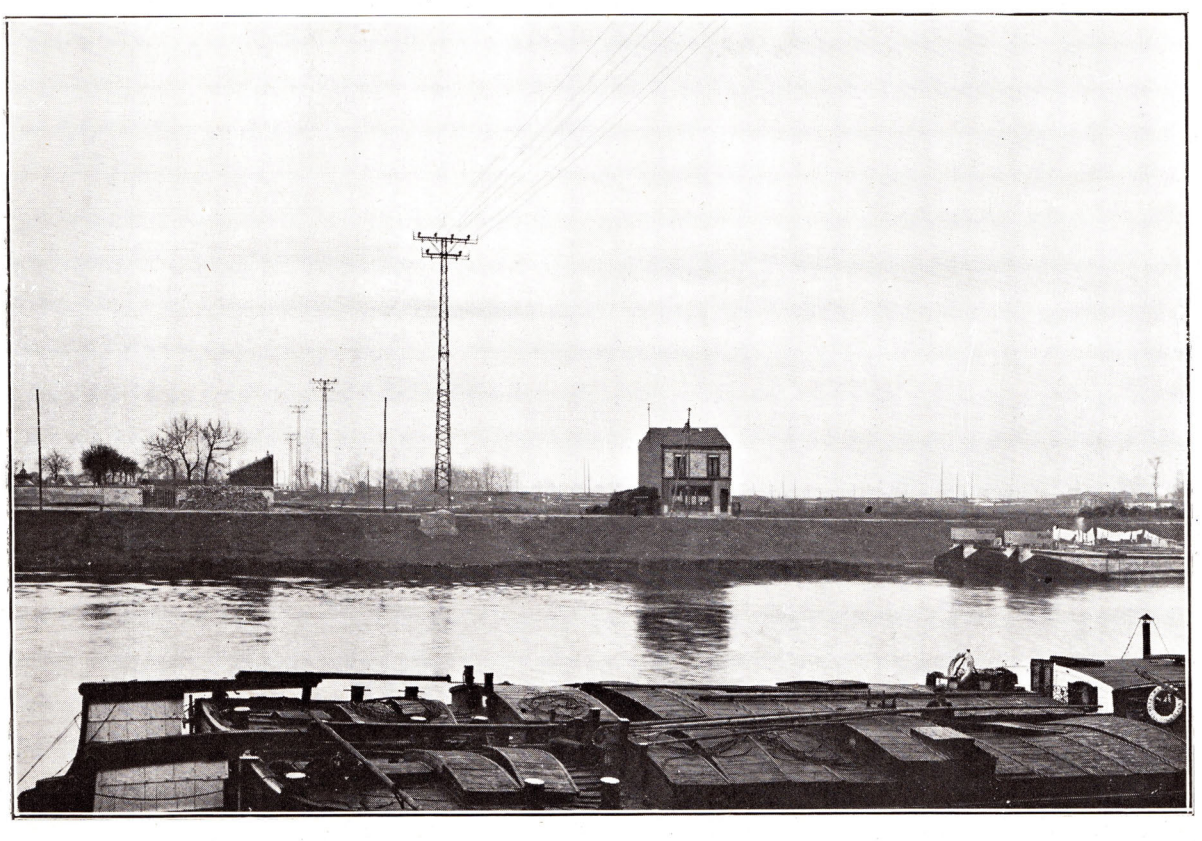


Fig. 7. — Paris-Creil 60 000 volt line. Crossing over the Seine at Saint-Denis Island.

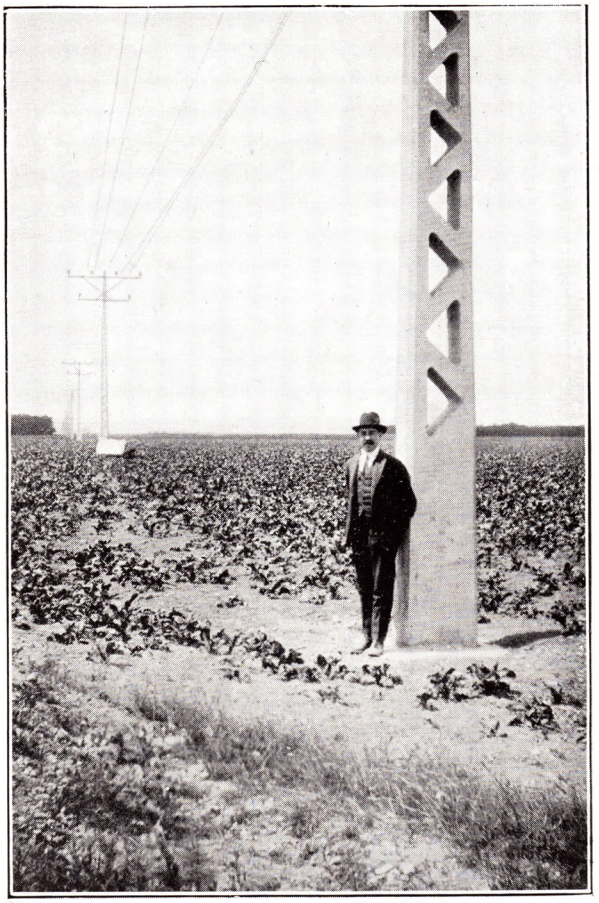


Fig. 8. — Paris-Creil 60 000 volt line. Straight-away section.

the various sub-stations to communicate directly with the central load dispatcher at the main station.

The total length of the 60 000 volt underground line around Paris will be 125 kilometers (1).

The copper conductors have a uniform section of 150 sq. mm. The cables will stand a continuous load of 30 000 kva without causing an increase of their temperature of more than 19° above the temperature of the surrounding earth.

In order to facilitate the dissipation of the heat, there are only two feeders and one pilot cable installed per each one meter of width.

(1) An important quantity of these feeders has been already furnished by the Compagnie Générale des Câbles de Lyon, 41, Chemin du Pré-Gaudry, at Lyon and also by the Forges et Ateliers de Constructions Electriques de Jeumont, at Jeumont (Nord). Another important order has been placed, partly with these manufacturers and partly with the Canalisation Electrique (at Saint-Maurice, Seine) and the Maison Geoffroy and Delore (28, rue des Chasses, at Clichy, Seine).

Certain of these various firms indicated above and the Société Industrielle des Téléphones (25 rue du 4-Septembre, Paris) have furnished the armored cables for medium voltage.

The loss due to induced currents in the lead covers is less than 1/6 of the corresponding copper loss.

The dielectric loss in the insulation is approximately 900 watts per kilometer of three-phase feeder.

OVERHEAD DISTRIBUTION. — The distribution system will be completed by a series of overhead lines.

There will be four main lines, which radiate from the central part approximately following the cardinal directions as follows :

Paris-Creil	Length	55 km
Paris-Mantes		45 —
Paris-Corbeil-Orléans		110 —
Paris-Meaux		40 —
Total length of the overhead lines		250 km.

The section Paris-Creil is now entirely completed. It comprises two 60 000 volt lines mounted upon single reinforced concrete poles with special structural steel towers for the crossings.

The line Paris-Mantes is being laid-out.

The line Paris-Corbeil-Orléans will be a part of the high tension system to be installed by the Compagnie des Chemins de Fer d'Orléans to connect the Eguzon hydro-electric station on the Creuse River to the line of the Union d'Electricité. The Eguzon station is being built by the Société l'Union Hydro-Electrique capitalized at 38 000 000 francs. The Union d'Electricité is interested in the creation of the last company and the Compagnie d'Orléans has also an important interest. The Union d'Electricité has been granted, by special arrangement, the general management and the exploitation of the interconnecting system.

As regards the line of Meaux, the preliminary lay-outs are being made.

It is also necessary to add that special arrangements have been made so as to permit the installation, at a later date, of incoming lines, now under study, for the transportation of hydro-electric power from a great distance. This power will be obtained from the Rhône, the Rhine or the Massif Central.

STUDIES RELATIVE TO THE OPERATION OF THE SYSTEM. — The study of the operating conditions has raised problems of all kinds, the solution of which has not always been of the easiest.

The necessary study of short-circuit currents, to determine the rupturing capacity of the circuit breakers, was made by the Compagnie Française pour l'exploitation des procédés Thomson-Houston (1) and the General Electric Company, by the patented experimental method of the latter company. These investigations have been a work of several months and have necessitated actual volumes of calculations.

The important investigations, made by MM. Clarke and Shanklin of the General Electric Company, have been of great assistance in the study of single-conductor cables and, especially, in the study of the circulating currents in the lead covers. These investigations have been continued

(1) Compagnie Française pour l'Exploitation des procédés Thomson-Houston, 10, rue de Londres, à Paris.

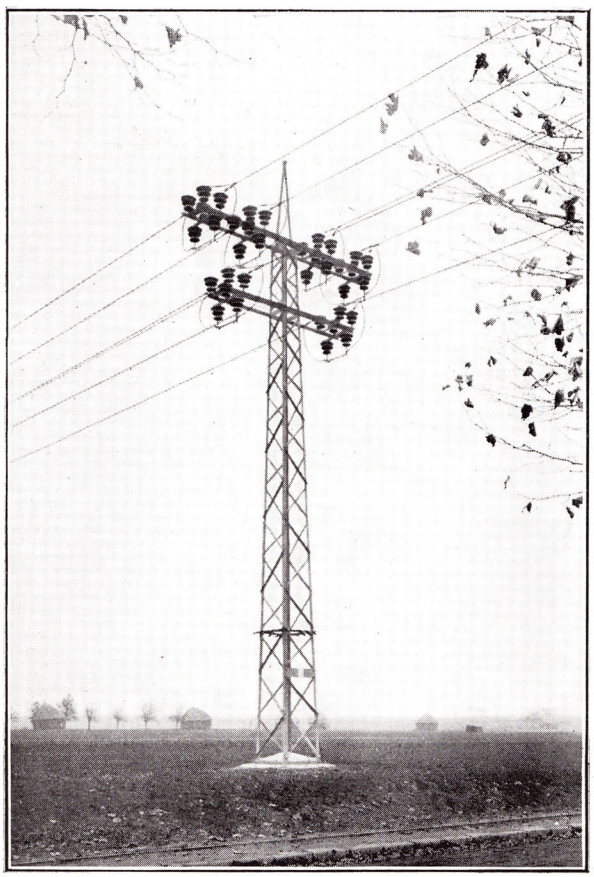


Fig. 9. — Paris-Creil 60 000 volt line.
Sectionalizing tower.

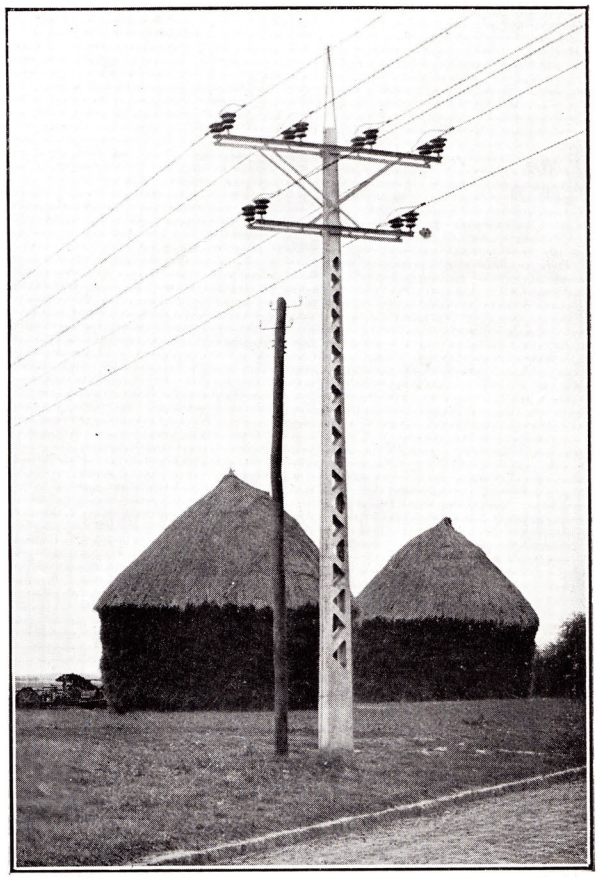


Fig. 10. — Paris-Creil 60 000 volt line.
Pole for highway crossing.

in close collaboration with the French cable manufacturers who have shown, in these circumstances, a keen spirit of initiative. M. Grosselin, himself, has taken a personal, particularly active and appreciated part.

The study of the phenomenon of resonnance has been made by M. Emile Brylinski, Technical Adviser of the Company, and he had made many extremely interesting investigations. M. Boucherot has also done work in this direction of the greatest value and has put at the disposition of the Union his exceptional experience and his great scientific knowledge, to which all electrical engineers rend homage.

The studies of the foreign specialists have been successfully completed and the engineers of the Union d'Electricité have obtained from them very valuable information.

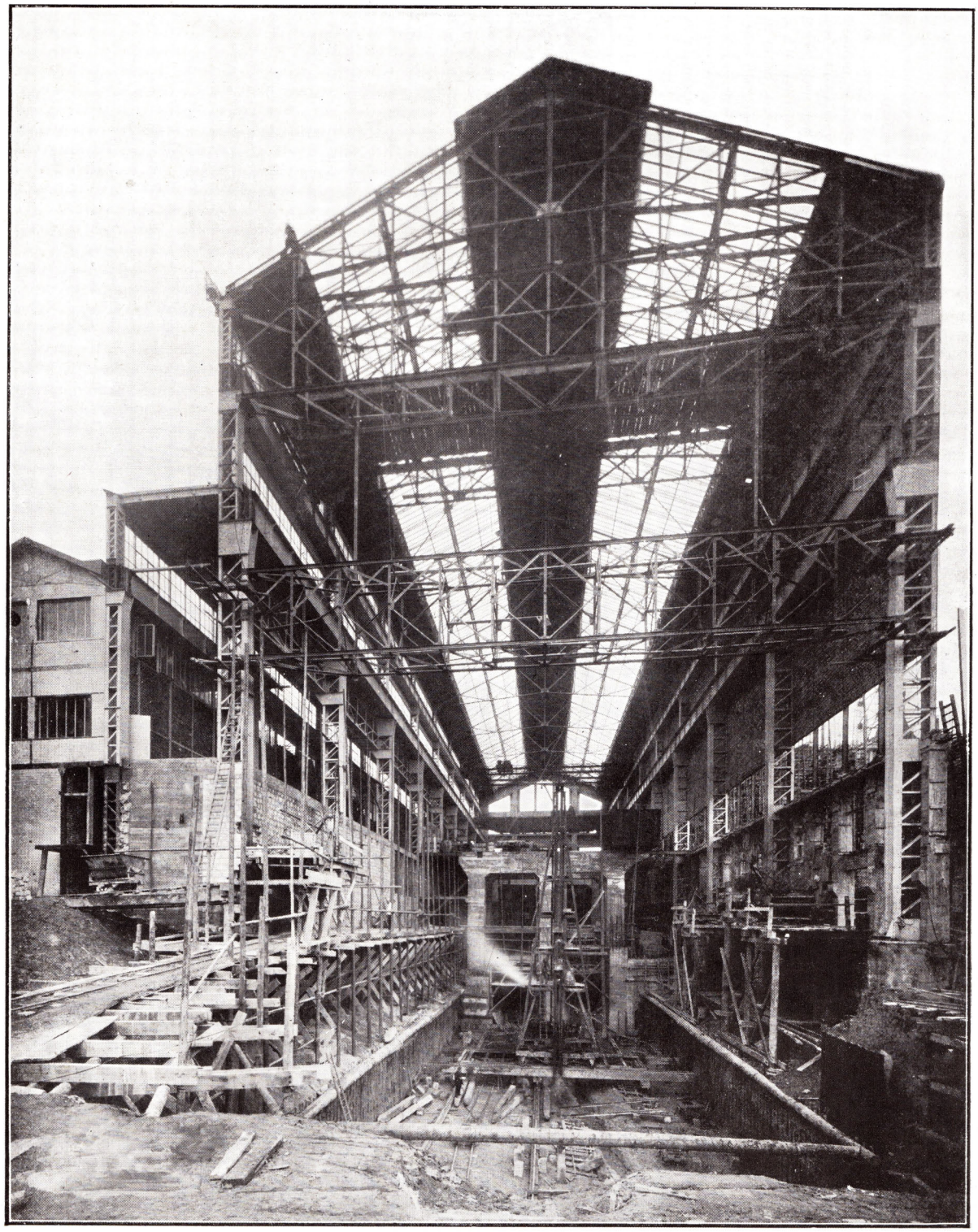


Fig. 11. — The Main Generating Room (South side) (December 1921).

The view showed in Figure 12 may be placed beyond the above and will demonstrate the progress of the erection. At the farther extremity, the Units No. 1 and 2 are being installed, while a pile-driver is placing the foundation piles for UnitNo. 5. An idea of the general proportions can be obtained by observing the size of the man located at the bottom of the sheet in line with the extension of the water canals.

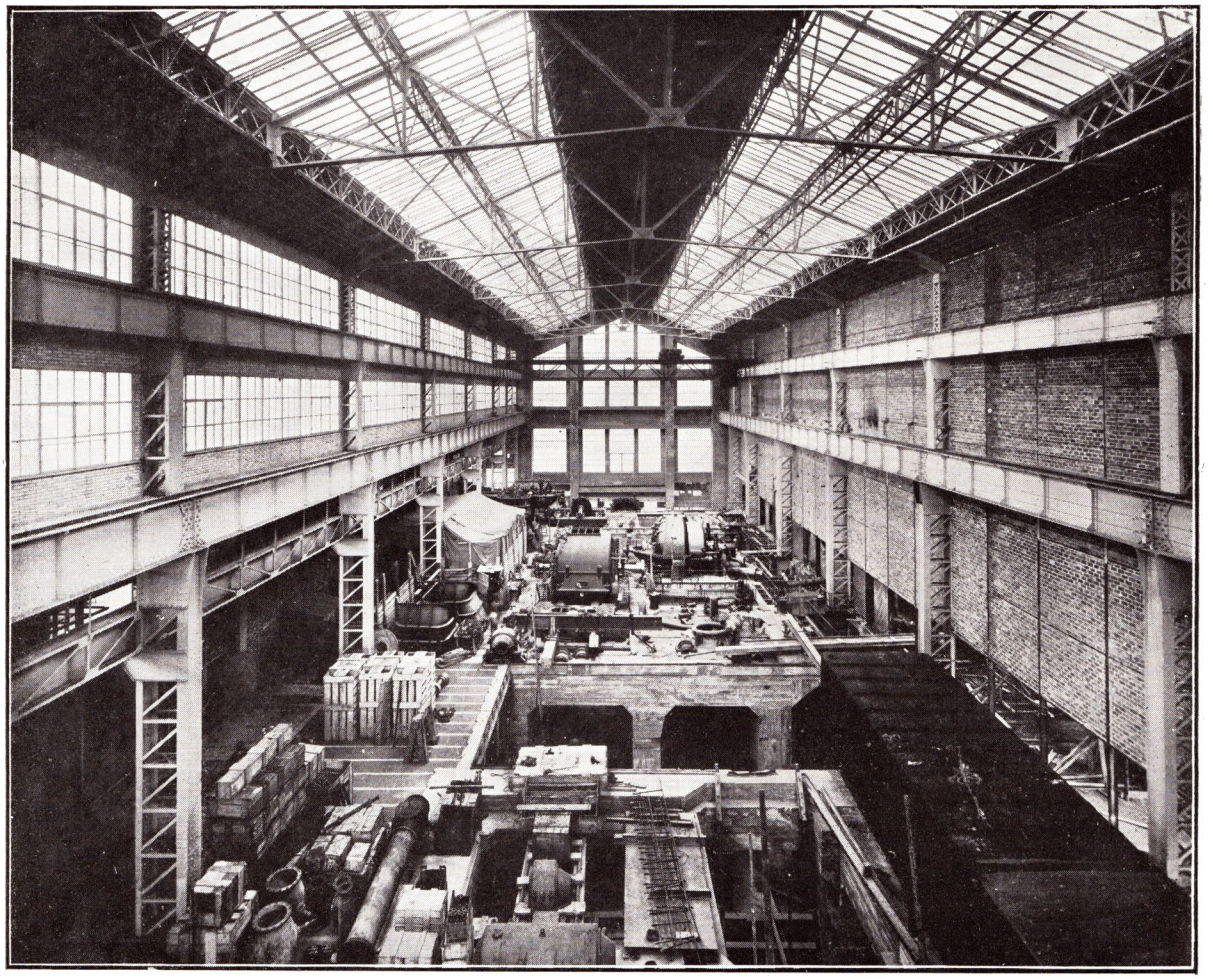


Fig. 12. — The Main Generating Room (North Side) Erection of Units No. 1 and 2 (December 1921).

CHAPTER II

GENNEVILLIERS POWER STATION

In order to meet, in the most economical way, the needs of the customers acquired by the Union d'Electricité, the Company decided, in 1920, to build at Gennevilliers a new power station of which the initial installed power would be 200 000 kw and eventually, increased to 320 000 kw.

Location. — The site was chosen on the left bank of the Seine, in the village of Gennevilliers, facing the town of Argenteuil and at a distance of 6 kilometers from the walls of Paris.

The total area of the land purchased by the Company was 11 hectares in one single piece.

The site has a frontage of 400 meters on the Seine and lays between the Railway bridge and the bridge of the Avenue of Argenteuil.

This depth of the site is limited to 300 meters by the main Paris-Rouen line of the State Railway.

This location provides the Company with excellent transportation facilities, both by rail and by water, and assures the supply of fuel under the most advantageous conditions.

Disposition of the Land. — A warf 160 meter long, the level of which is 50 cm. above the highest flood stage, permits the coming along side of

Fig. 13. — Wall along the Seine and Dredge — View taken from the water intake (September 1921).

barges of 1 000 tons and above. The Seine has been dredged at the base of the warf, due consideration having been taken of the projects for deepening the bed of the river, which may be executed in the future. This warf will be lengthened to 400 meters if future conditions warrant.

The coal storage extends parallel to the Seine. It has a width of 40 meters and a length of 300 meters and provides storage space for 60 000 metric tons of coal. A part of the storage-coal may eventually be kept under water.

The station has been built so as to permit its free extension in all directions. A free space of 3 hectares has been reserved to install, at a later date, 150 000 volt switch gear which will constitute the terminals of the hydro-electric power lines.

The axis of the generating room is perpendicular to the Seine. The total length of the condenser water intake canals does not exceed 70 meters.

The outlet empties 130 meters down-stream of the water inlet. The hot condenser water discharges upon the surface with a velocity of 2 meters per second and the current extends, in the river and below the outlet, an additional 500 meters.

Under these conditions, considering the cross section area of the Seine, which, at this point is over 150 meters, the volume of water, included between the inlet (1) and the extremity of the current caused by the discharge, is sufficient to permit the operation of the power-plant at full capacity

(1) See page 13, plans, profile and sectional elevation of the water inlet of which the mechanical sluice gates have been furnished by the firm Beaudrey et Bergeron, 14, boul. Ornano, à Paris.

(250 000 kw) for a three hour period without causing a rise of water temperature of over 4° centigrade, even if the current of the river would be entirely stopped.

The lay-out of the railway sidings has been made with a particular object in view : the incoming line branches into three parallel tracks, one along the northern side of the coal storage, the second along the southern side, and the third runs transverse to the generating room and the boiler house. An additional track connects with the latter and extends to the large shop, which has rendered great services during the period of construction and which will be used, in the future, as a shop for rewinding the material of the power house and that of the numerous sectors supplied by the station.

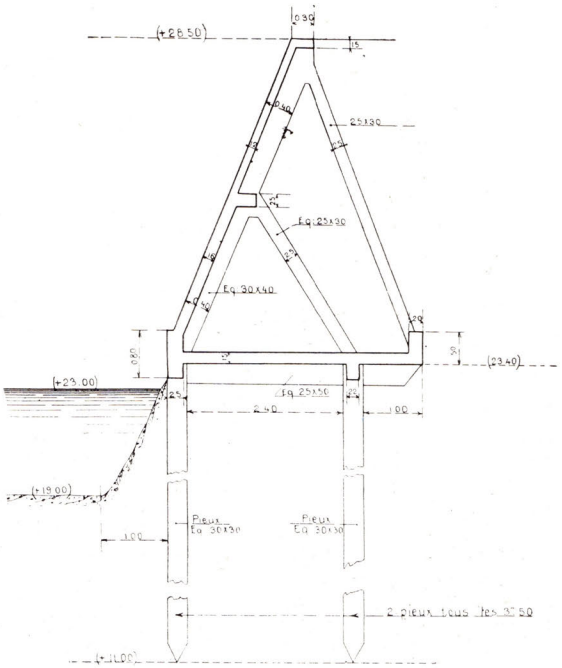
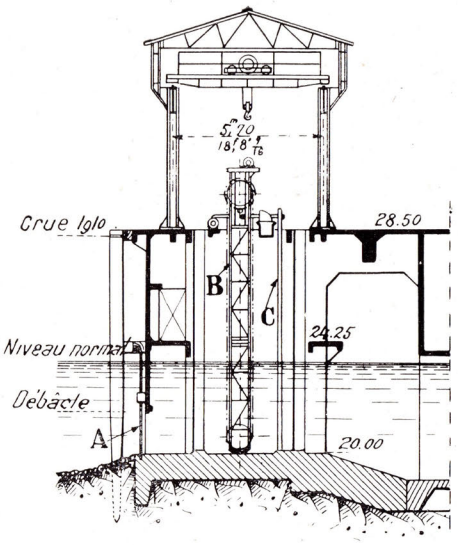
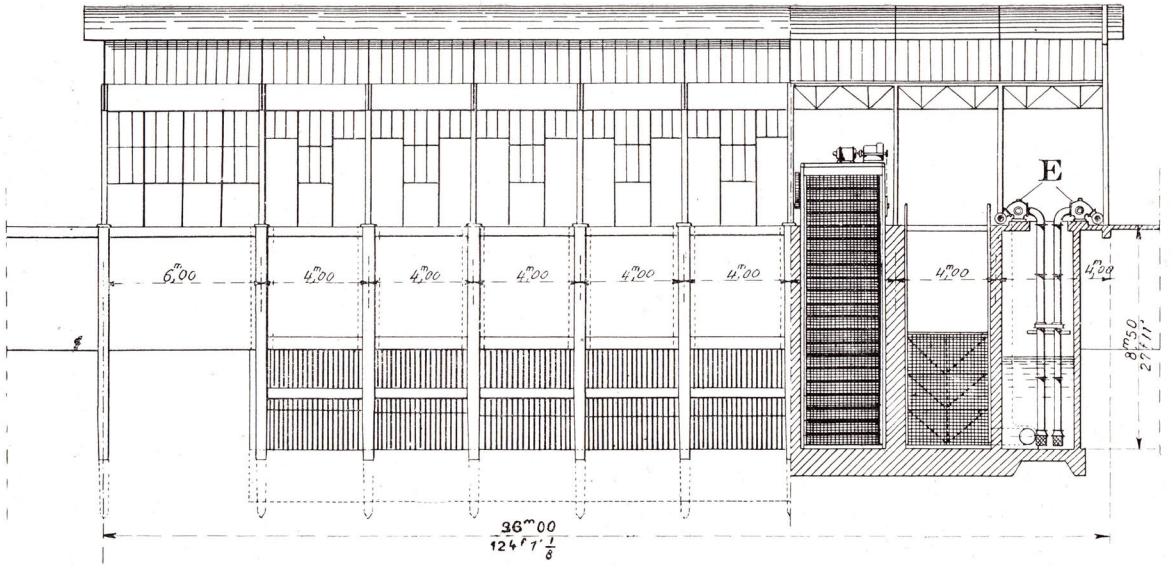


Fig. 14. — Section of wall along the River.

Fig. 15. — Water outlet tunnel during construction. — (View taken from the Seine end) (December 1921).





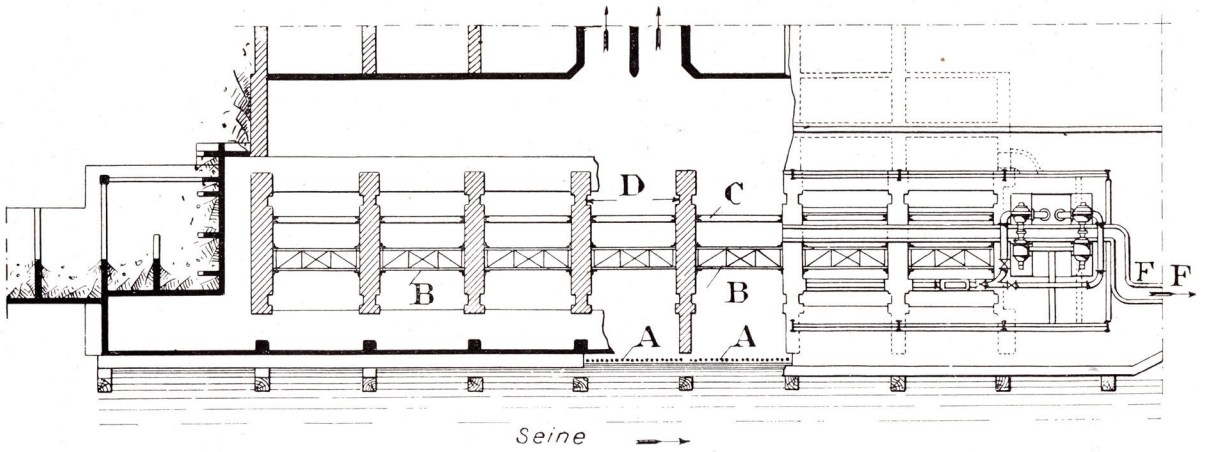


Fig. 16, 17, 18.

Section and longitudinal view of the water intake.

a) Forward Screens. (Crue) Flood.
b) Moving Screens. (Niveau normal) Normal level.
c) Safety Screens. (Débâcle) Low.
d) Coffer-dam grooves.
e) Water pumps.
f) Scavenger water-way.

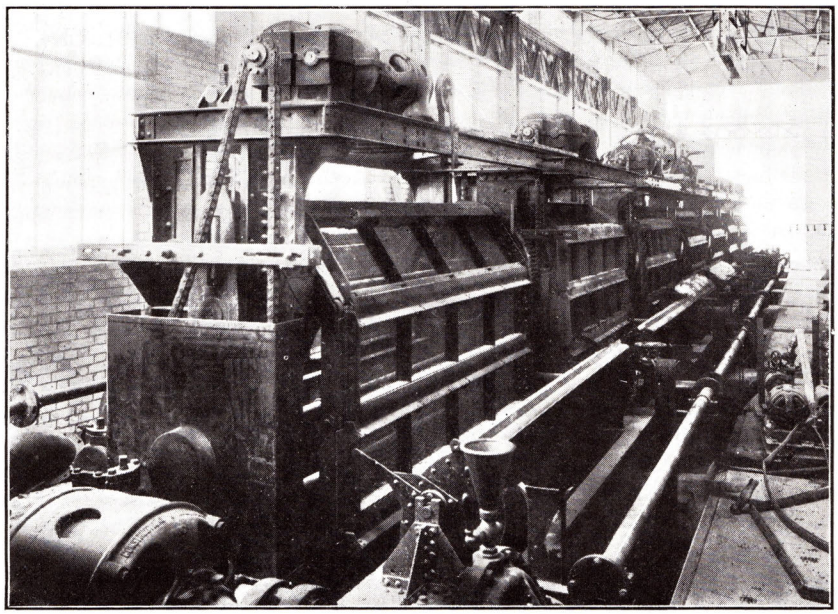


Fig. 19. — Interior view of water intake.
Moving mechanical Screens furnished by Beaudrey et Bergeron.

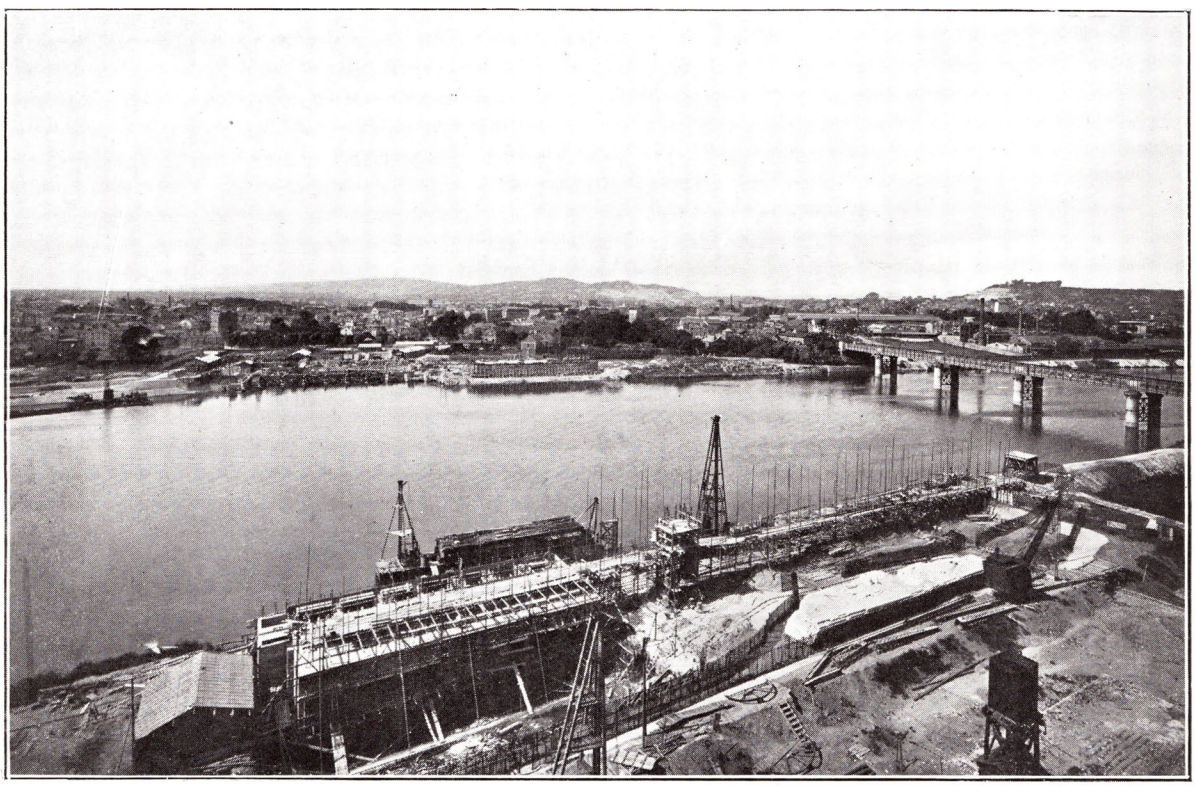


Fig. 20. — Water-intake and wall along Seine during construction.
View taken from the Main Generating Room (July 1921).

GENERAL LAY-OUT AND BASIS OF THE PROPOSED SCHEME

The Company intends to carry out a double scheme :

1°-To obtain the maximum possible efficiency without excessive complications.

2°-To reduce the installation expenses to a minimum without reducing factor of safety of the installation.

1° The first condition was necessitated by the particularly high cost of coal in Paris. At the present time, the price per ton in barges is still above 100 francs. The Company has assumed that this price will decrease rapidly to 70 francs and after several years, it will be in the vicinity of 60 francs. The Company has based its amortization program on these figures. During the period in which the price of coal is above this latter value, additional economies will be put into effect, which will permit of the writting-off of abnormal expenses, which an enterprise of such an importance will necessarily carry under present conditions.

Therefore, with a yearly production of 600 000 000 kwH, which the Company will normally reach in a few years, an economy of production of 1 0 /0 represents an annual profit of 400 000 francs.

From the above figures it is seen that the Union is justified in installing certain apparatus which, for stations operating under more favorable condition as to the price of fuel, would have been considered too expensive and nonpaying.

The main characteristics of the apparatus are as follows :

Steam Pressure. — The most advantageous pressure as regards the operation of the steam turbine is approximately 25 kilogs. For pressure in excess of the above, the thermodynamic efficiency increases but slightly and the mechanical losses, particularly due to friction in the steam, increase fairly rapidly.

This pressure does not cause any special difficulties in the construction of the machines. It can be adopted for boilers and piping if certain precautions are taken.

Therefore a pressure of 25 kilogs has been adopted, but the turbines have been designed so as to operate at full capacity with a pressure at the steam-inlet of as low as 20 kilogs.

Steam Temperature. — For superheat, the consideration of the thermodynamic efficiency alone, demanded the adoption of the highest possible value.

The question of security has been the limiting feature. Beyond a temperature of 400° C., cast parts suffer continual alteration in shape. By adopting steel for the high pressure stage, a working temperature of 400° can be utilized. Due, however, to the impossibility to control absolutely the temperature, it was decided to reserve a margin below this figure.

For the above reasons, an operating temperature at the inlet has been chosen as between 350° and 375° C.

The experience of many years in the Asnières station of the Société du Triphasé has demonstrated that the above choice is entirely satisfactory, even when employed with turbines having cast-iron high pressure parts.

Characteristics of the Turbo-Generator units. — A careful examination of the results obtained on large units, both in America and in Germany, determined the adoption of 40 000 kw. In fact, this capacity corresponds exactly to the requirements of the service, especially as regards night operation, as well as having been the maximum that could be obtained in single units at 1 500 rpm., at the time of the placing of the orders.

Units of the above capacity realize the maximum efficiency and the minimum operating expenses and first cost.

In consideration of the security of operation, 6.000 volts was chosen as the tension of the generators. The immense power involved made it impossible to successfully construct switch gear to operate at the above voltage. Therefore, it was decided to wire each generator to its individual step-up transformer (6 000 to 60 000 volts) without interposing any switch gear.

The switching will, therefore, all be done at 60 000 volts, oil circuit breakers for this voltage

and the capacities envolved showing no difficulties in regard to construction.

Boiler Characteristics. — The same consideration led to the adoption of boilers of the largest capacity compatible with the pressure of 25 kg. Various considerations, particularly the examination of the various mechanical grates, and also, the necessity of being able to burn a great variety of coal, ranging from washed coal having 20 o/o volatile to coke dust, have influenced the choice of mixed equipment.

Half of the boilers installed will be Stirling with Riley grates and the other half Babcock and Wilcox with Babcock and Wilcox grates.

For the first class of boilers a heating surface of 2 100 square meters was adopted.

For the second class a heating surface of 1 330 square meters was chosen, two units being placed back to back forming a double unit of 2 660 square meters heating surface.

Thermic Balance. — The Union made a long and minute investigation of the various arrangements both those which have been put in practical operation and those proposed, the following being the principal systems investigated :

The use of back pressure turbines, exhausting into a receiver, and operating in parallel with low pressure units, a regulating device controlling the thermic balance ;

The use of turbine driven auxiliaries operating at a back pressure and exhausting into the main turbine-receiver ;

The use of reheaters between the high and low pressure.

After all consideration, the Union adopted the following arrangement which seems to provide the best compromise and insures the following requirements :

Economy,

Security,

Simplicity of operation.

The auxiliaries are principally operated by electric motors, which receive their power from the main buss through the intermediary of step-down transformers.

As a safety precaution, a number of the auxiliaries are also provided with individual turbines, which can be operated continuously or put in operation instantly in case of emergency.

As an additional safety precaution, two small turbo-generators of 3 000 kw each are provided ; each one being sufficiently powerful to operate the principal auxiliaries in case of emergency or operate the total auxiliaries in service during the night when only one main generator is in service.

Each main turbine is provided with two bleaders taking steam from the intermediate stages, which is used to reheat the condensate. The reheating is entirely automatic and raises the temperature of the condensate to 85° C at full load and to 70° C at half-load.

The exhaust steam from various feed pumps, which are kept in constant operation, further reheat the condensate to 100° C. A special regulator maintains same without exceeding this temperature, thus reducing the evaporation losses.

The feed water therefore enters into the economizers at a temperature of 100°. The surface of these economizers is proportioned so that the temperature of the water at the outlet attains about 160° C.

Under the above conditions, the temperature of the hot gases coming from the economizers is approximately 220°. This temperature is too high and if heat is not further extracted, a loss of efficiency would occur. To avoid this, a feed-air heater is installed at the economizer outlet. This heater is designed to preheat the air going to the boilers to 90° C. and to lower the temperature of the gases to 150° C. at the maximum.

2° The reduction in installation expenses has not, in any way, been obtained by a reduction of material which, on the contrary, has been amply maintained. No sacrifice has been made either in the dimensions of the material or in the quantity of stand-by apparatus.

The use of large capacity units has resulted in a large reduction in unit cost, which well stand as a monument to engineering genious.

This reduction has permitted a very low first cost for the piping and in addition a reduction in the losses and cost of up-keep.

In the same line, the economizers have been designed so as to reduce the size of the units and, at the same time, reduce the losses by radiation and minimize the cost of maintenance. For reasons of economy, the economizers have been located directly on top of the boilers. This has complicated

the boiler frames and setting, but has resulted in a diminution of the boiler-room area.

The same principles have permitted the reduction to a minimum of the lengths of the circulating water canals and pipes, and decided to a certain extent the adoption of single-flow condensers.

In the construction of the main buildings and the various shops, no unnecessary expense has been occurred for useless ornementation or luxury. General lines of architecture alone have been employed.

Furthermore, in order to avoid all loss of time and discussion of minor details, the Company decided to be its own contractor. A department was therefore organized and made the necessary designs and plans, which such an undertaking required. The company was therefore enabled to consider each line of apparatus as a unit and to purchase same under the best possible conditions and at the minimum price.

The company further built in the vicinity of the station, a complete new machine and blacksmith shops, having a floor-space 2 000 sq. meters. In these shops, it was possible to do much of blacksmith, pipe, structural and miscellaneous machine work with a great saving of time and expense.

At the same time, through the kindness of the Administration of the Chemins de Fer d'Orléans, which readily gave its help, the Union was able to organize a complete system of inspection of the material during manufacture. It was possible to follow the construction of the material, piece by piece, and to intervene, in case of necessity, without causing serious delays.

These different measures, produced the desired results, both as regards delays in delivery, which never exceeded eighteen months, and in the cost of construction, which will be discussed later.

Naturally, a heavy burden fell on the personnel of the Union, under which it held up remarkably well, showing great intelligence and devotion to duty, which never lagged.

DATA ON THE MATERIAL

Boilers. — The present equipment of the station is as follows : Boilers : 5 Stirling.
— 20 Babcock.

I. STIRLING BOILERS

Manufacturer : Compagnie de Fives-Lille (1).

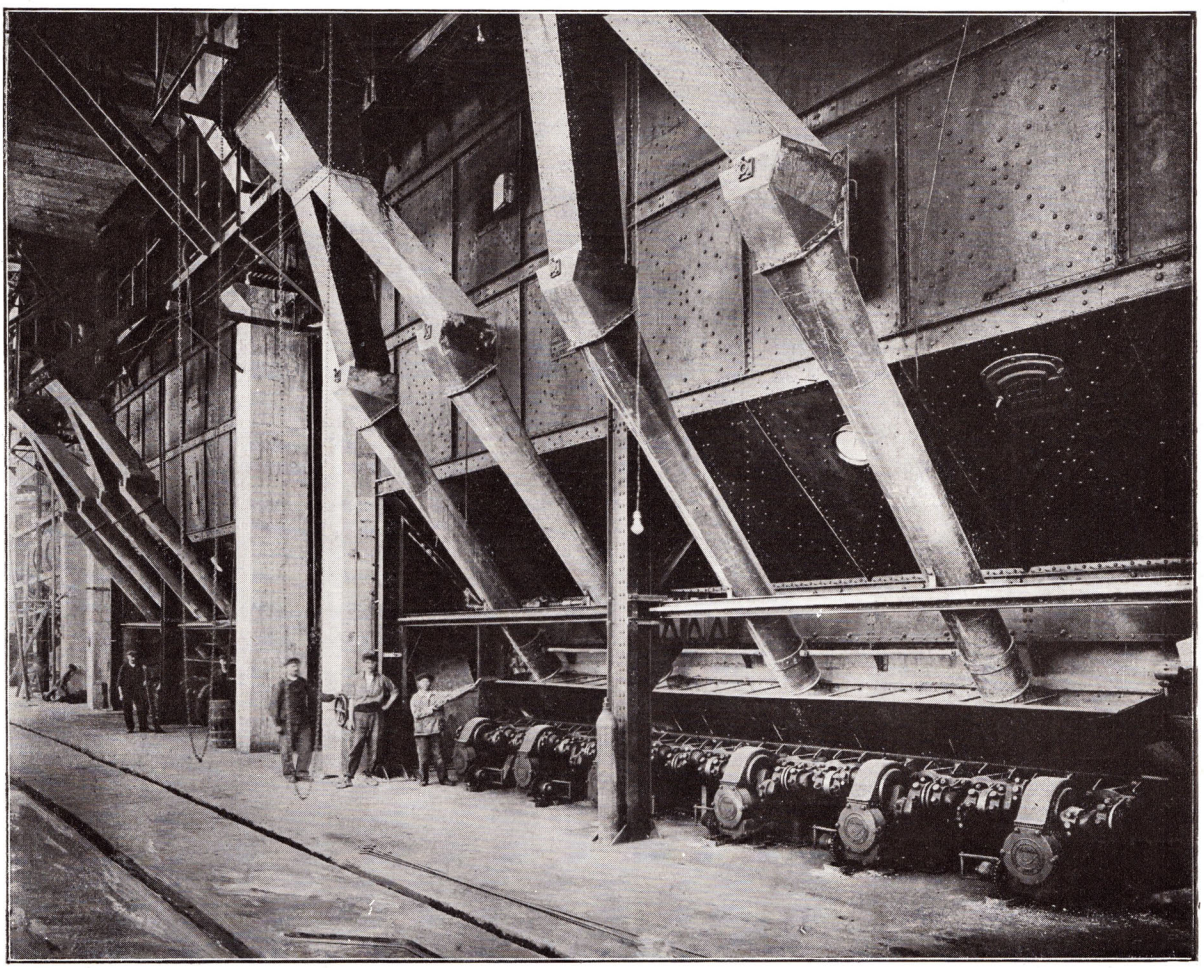


Fig. 21. — Sterling Boilers furnished by the Compagnie Fives-Lille equipped with Erith Riley mechanical grates. View taken from the central boiler room aisle.

Operating pressure	25 kilos.
Tubular heating surface per unit	2 100 sq. m.
Superheater heating surface	1 000 —
Volume of the water at normal water-level	81 000 litres.
Volume of the steam at normal water-level	20 000 —
Steam temperature	375°
Steam generation, normal, per hour.	60 000 kilos.
Steam generation, accelerated, per hour	80 000 —
Guaranteed efficiency (boiler only)	75 0/0
Grates : Riley (1).	

(1) Compagnie de Fives-Lille pour Constructions Mécaniques et Entreprises, 7, rue Montalivet, Paris.

(1) These grates have been furnished by Fama, Société Anonyme, 8, rue Blanche, Paris.

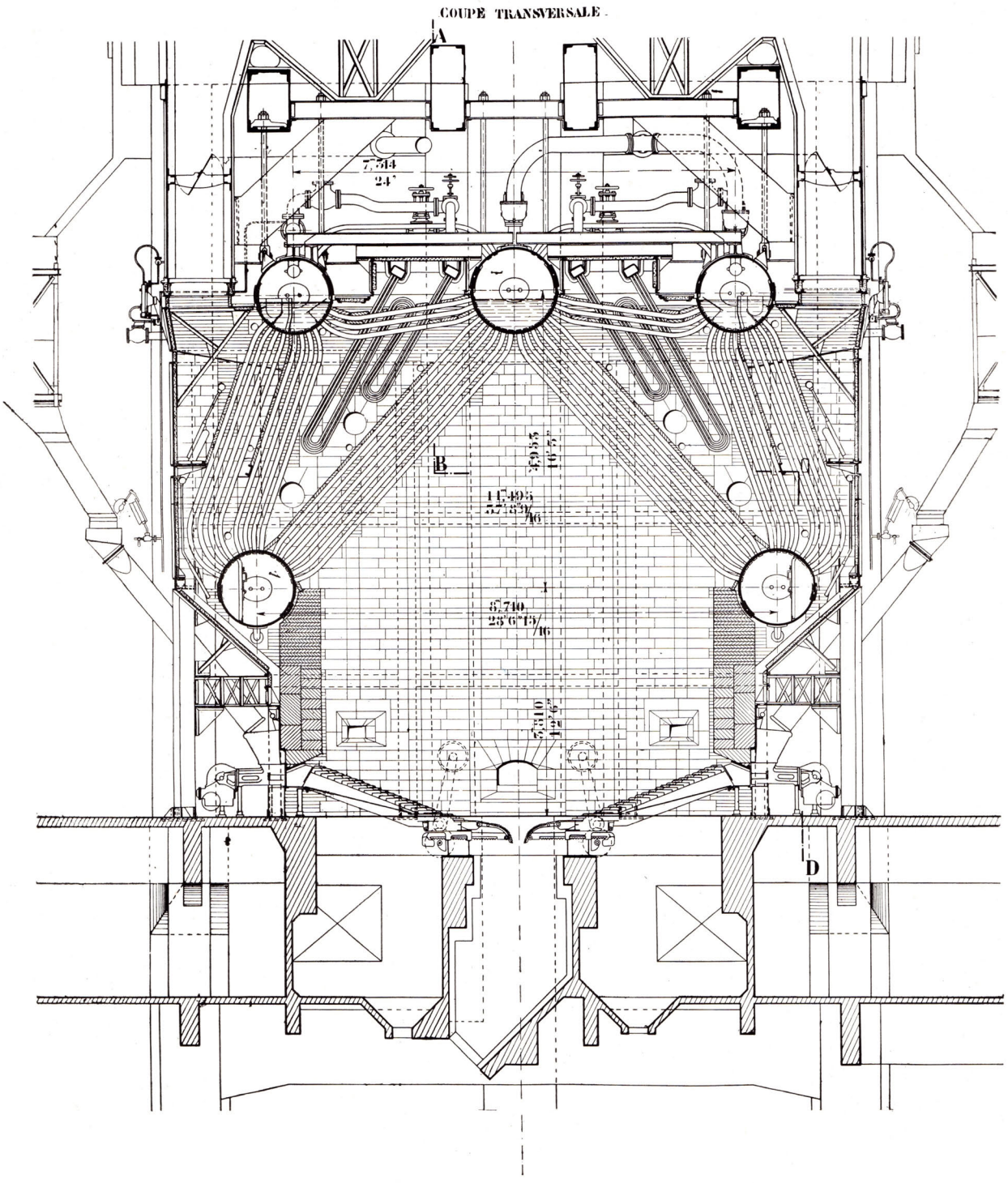
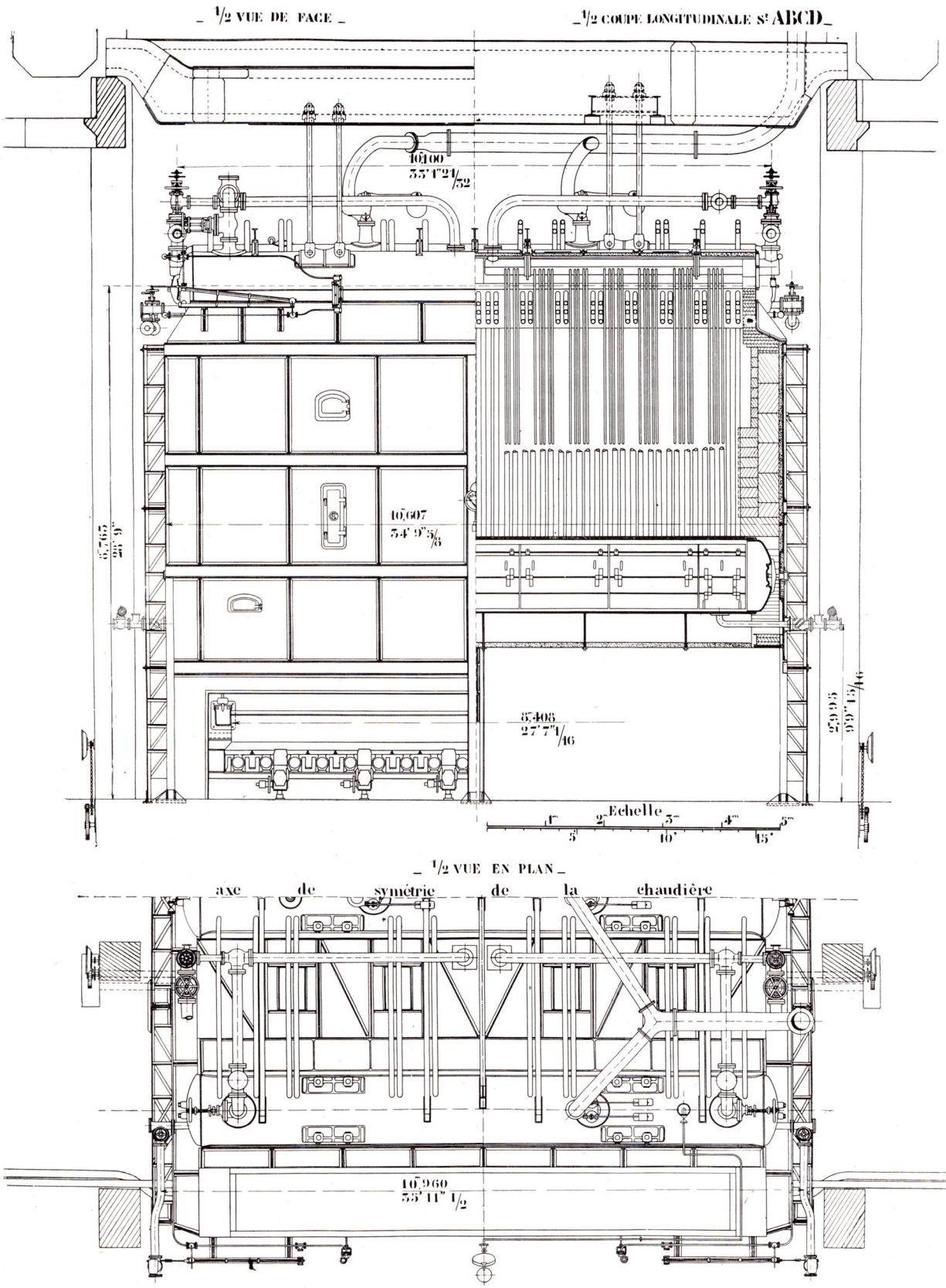


Fig. 22, 23 and 24 (Pages 20 and 21). Sterling Boilers furnished by the Compagnie Fives-Lille — Section.
Fig. 22. — Longitudinal section.
Fig. 23. — 1/2 view of front and 1/2 view of longitudinal section.
Fig. 24. — 1/2 plan view.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_ 1/2 COUPE LONGITUDINALE St ABCD _
10,100
33' 1" 21/32
10,607
34' 9" 5/8
8,765
28' 9"
8,408
27' 7" 1/16
2,995
9' 9" 15/16
Echelle
1m 2m 3m 4m 5m
5' 10' 15'
_ 1/2 VUE EN PLAN _
axe de symétrie de la chaudière
10,960
35' 11" 1/2

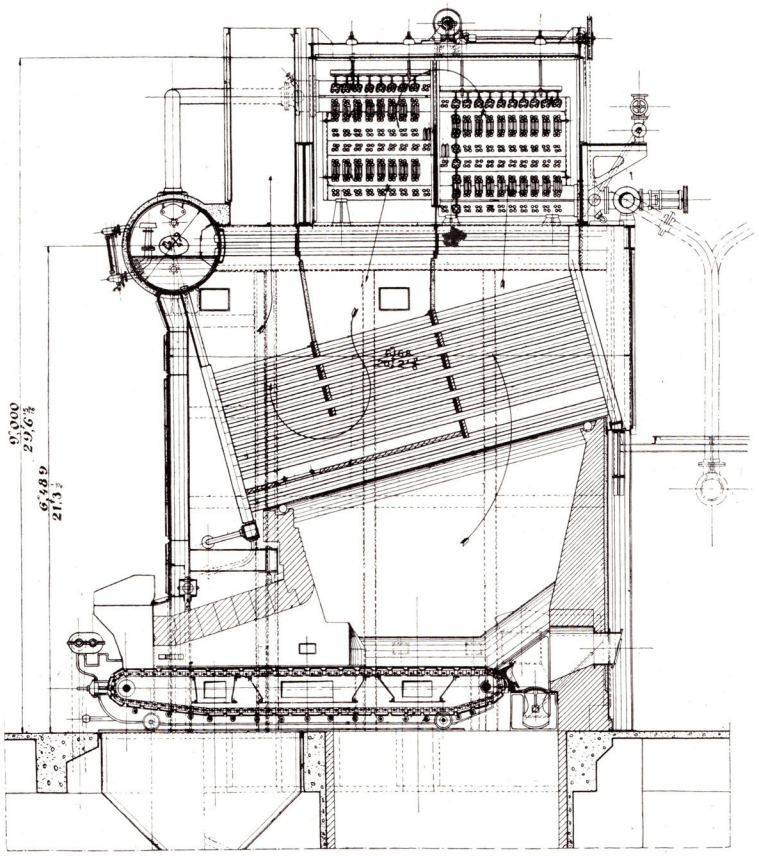


Fig. 25. — Babcock and Wilcox Boilers. — Longitudinal section.

II. BABCOCK & WILCOX BOILERS

Manufacturer : Société française des Constructions « Babcock et Wilcox » (1).

Operating pressure	25 kilos.
Tubular heating surface per unit	1 330 sq. m.
Superheater heating surface	760 —
Volume of the water at normal water-level	26 450 litres.
Volume of the steam at normal water-level	16 520 —
Steam temperature	375°
Steam generation, normal, per hour	40 000 kilos.
Steam generation, accelerated, per hour	53 000 kilos.
Guaranteed efficiency (Boiler only)	75 0/0

Grates : Babcock and Wilcox, 1920 (2).

The efficiencies apply using coal of 7 000 calories per kilo, 8 to 10 0/0 ash content, and a feed-water temperature of 160° C. at the Boiler inlet.

(1) Société française des Constructions « Babcock et Wilcox », 48, rue La Boétie, Paris.

(2) These grates have been furnished by the Société française des Constructions « Babcock et Wilcox ».

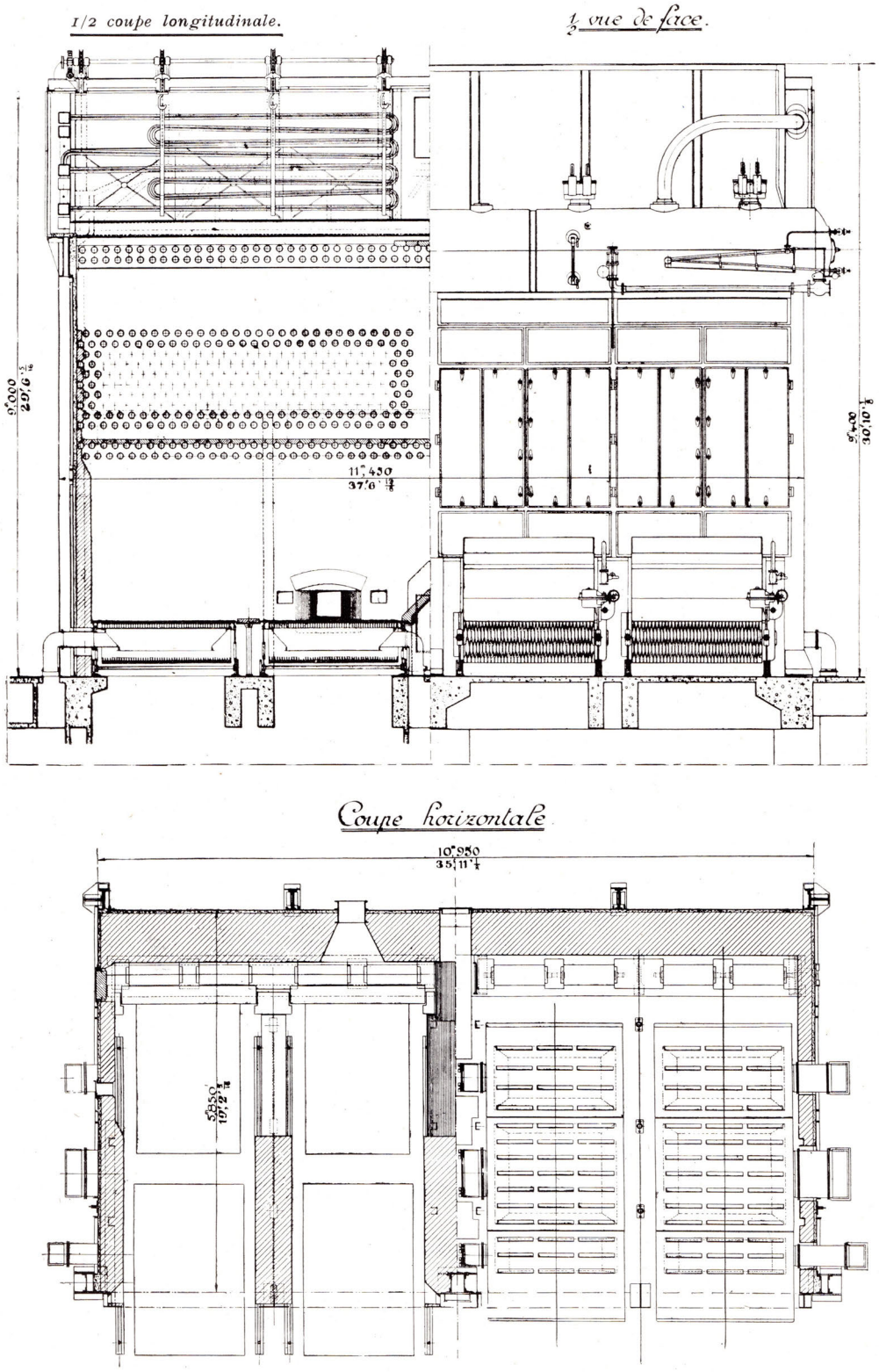


Fig. 26 and 27. — Babcock and Wilcox Boilers.

Fig. 26. — 1/2 view of longitudinal section. 1/2 view of front section. — Fig. 27. — Horizontal section.

Economizers. — Each set comprises :

Special coil water heater.

Sheet steel air pre-heater (1).

The characteristics of the economizers for use with the Stirling boilers are :

operation for the two series of apparatus are the following :

Temperature of the water at the inlet	90°
Temperature of the water at the outlet.....	150°
Temperature of the air at the inlet	30°
Temperature of the air at the outlet.....	90°

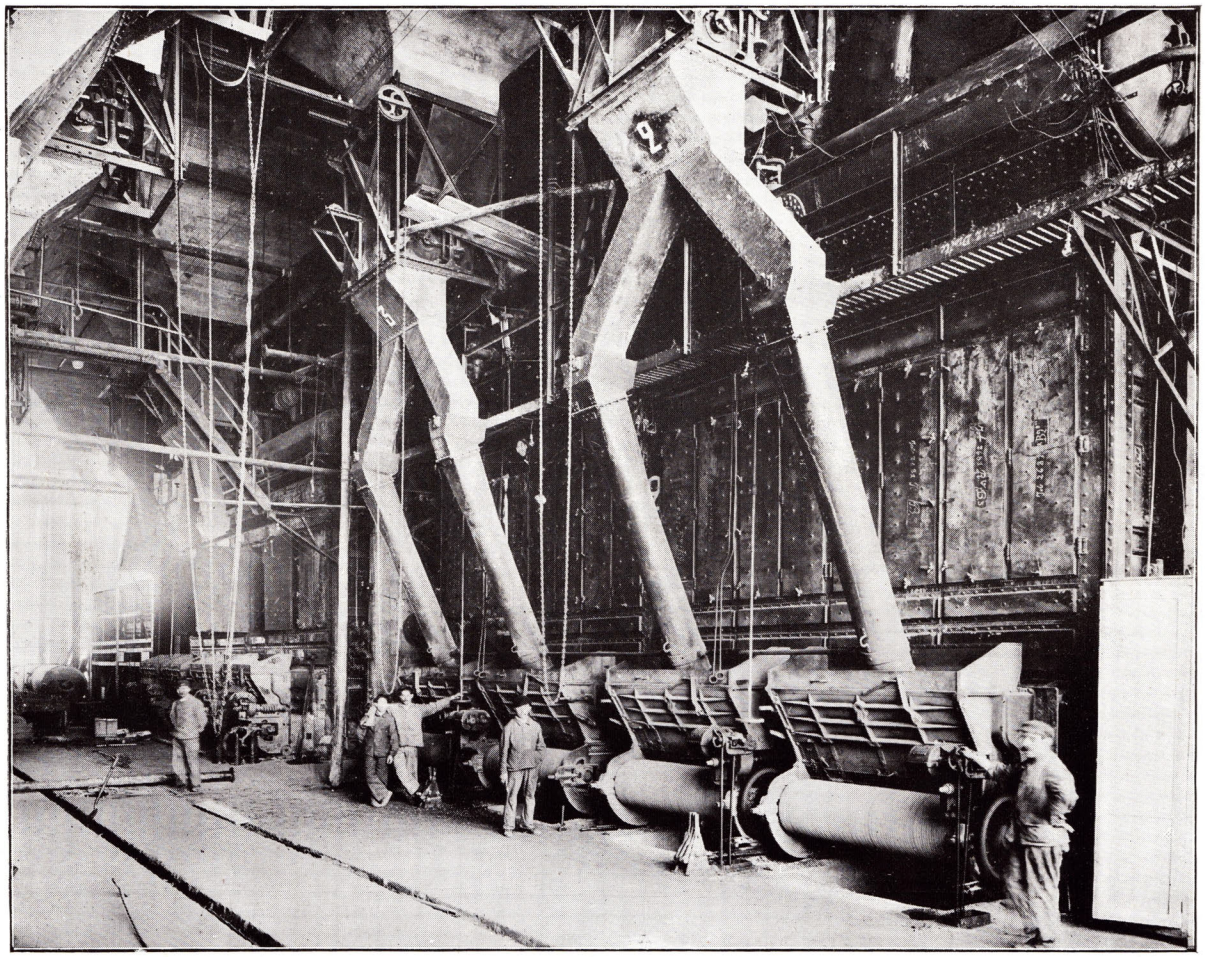


Fig. 28. — Babcock and Wilcox Boilers. View taken from the central boiler room aisle.

Tubular heating surface	1 200 sq. m.
Air preheating surface	1 790 —

The characteristics of the economizers for use with a block of two Babcock boilers are :

Tubular heating surface	1 600 sq. m.
Air preheating surface	2 240 —

The guarantees under conditions of normal

Temperature of gases at the economizer inlet.....	340°
Temperature of gases at the economizer outlet	220°
Temperature of gases at the preheater outlet.....	150°

The stacks are of the Louis Prat metallic type (1)

(1) This set was designed by the Union d'Electricité with the collaboration of the Etablissements Paul Kestner; The Union Thermique, 113, boulevard Jean-Jaurès, Boulogne-sur-Seine (Seine) ; Etablissements Emile Prat-Daniel, 64, rue de Miromesnil, à Paris.

(1) Société Louis Prat, 21, rue Lord-Byron, Paris.

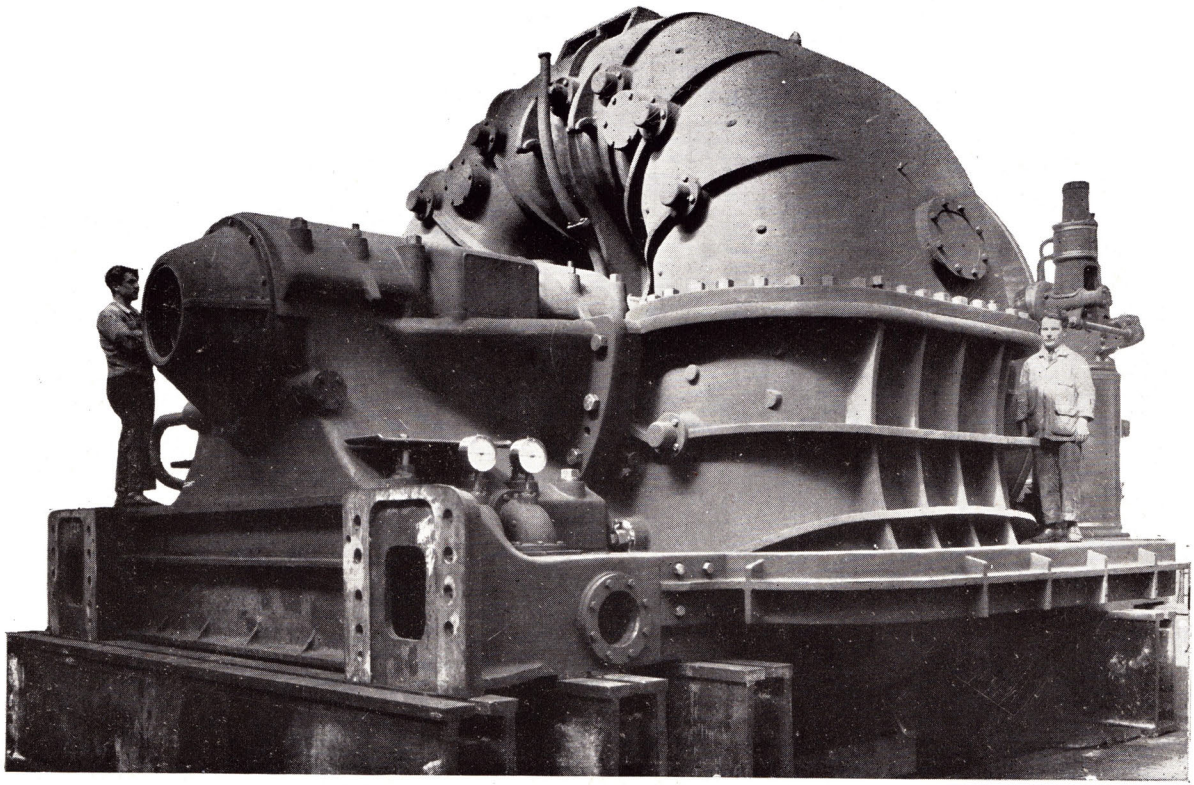


Fig. 29. — 40 000 kw Turbine. View taken at the factory.

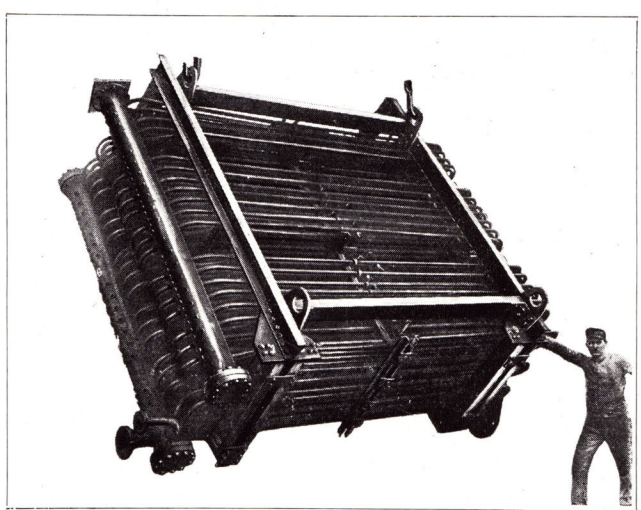


Fig. 30. — View of economizer element.

Turbo Alternators. — The present equipment comprises five units of 40 000 kw each.

The station has been built to permit the installation of a sixth identical unit.

An enlargement for the installation of a seventh and, eventually, an eighth unit of the same type has been provided for.

and by Schneider and Company for the electrical part.

The engineering Department of these important Companies have worked in close collaboration with the Union to attain the common end.

The characteristics of all the sets are identical, their main characteristics are the following :

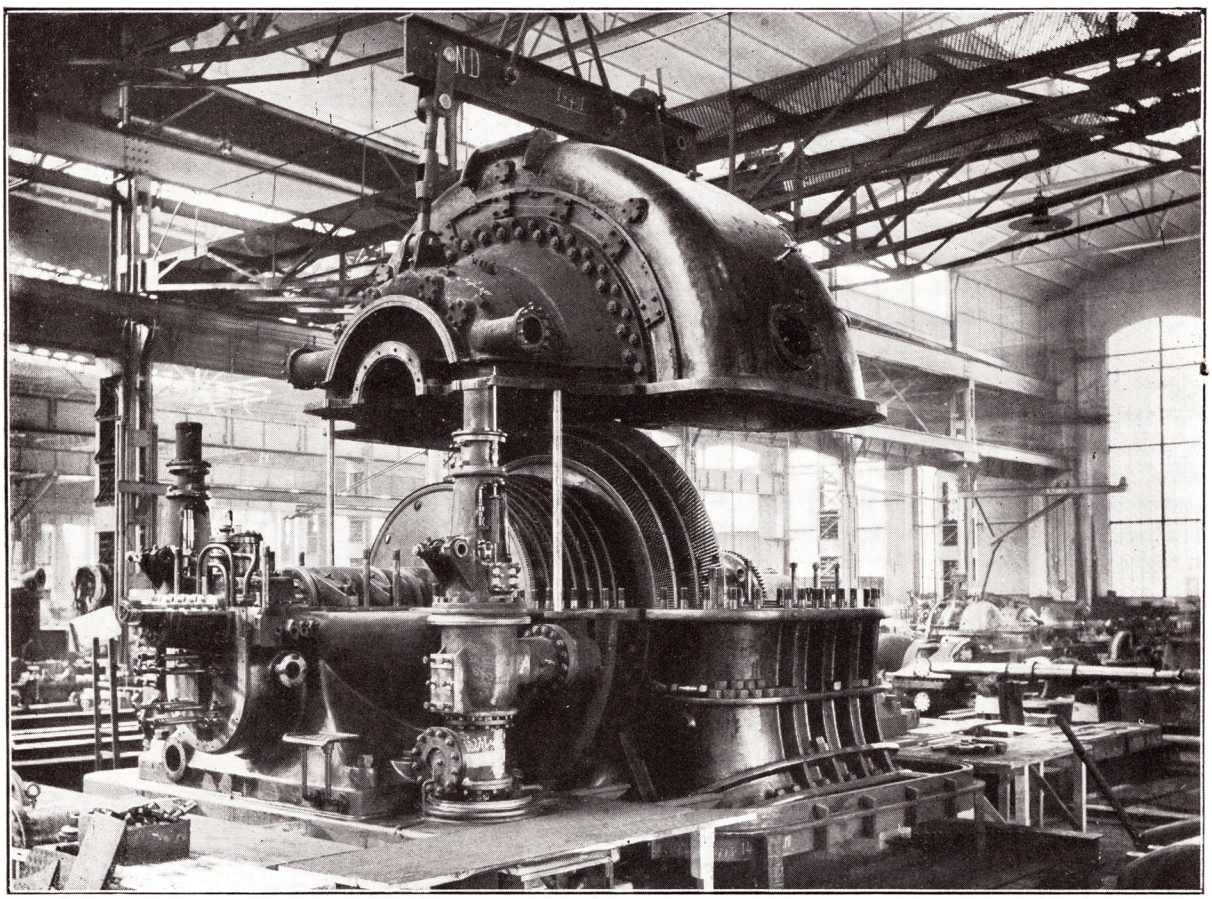


Fig. 31. — 40 000 kw Turbine. View taken during assembly at the factory.

The five present sets are of the same type Zoelly, all indentical parts are interchangeable.

Three complete units were manufactured by the Société Alsacienne de Constructions Mécaniques (1).

One complete unit by Schneider and Company (2).

One unit by Escher Wyss (3) for the steam parts

Number of revolutions per minute..	1 500
Pressure at the inlet.....	22 kil. effect.
Temperature at the inlet	375°
Frequency	50 cycle.
Normal voltage	6 000 volts.
Normal power	44 000 Kva.
The turbine can develop 40 000 Kw with a pressure of 20 kilos at the inlet.	
Regulation (8 P. F.)	50 0/0

(1) Société Alsacienne de Constructions Mécaniques, Belfort.
(2) Schneider et Co., 42, rue d'Anjou, Paris.
(3) Société Anonyme des Ateliers de Constructions Mécaniques Escher Wyss et Cie, Zurich (Switzerland).

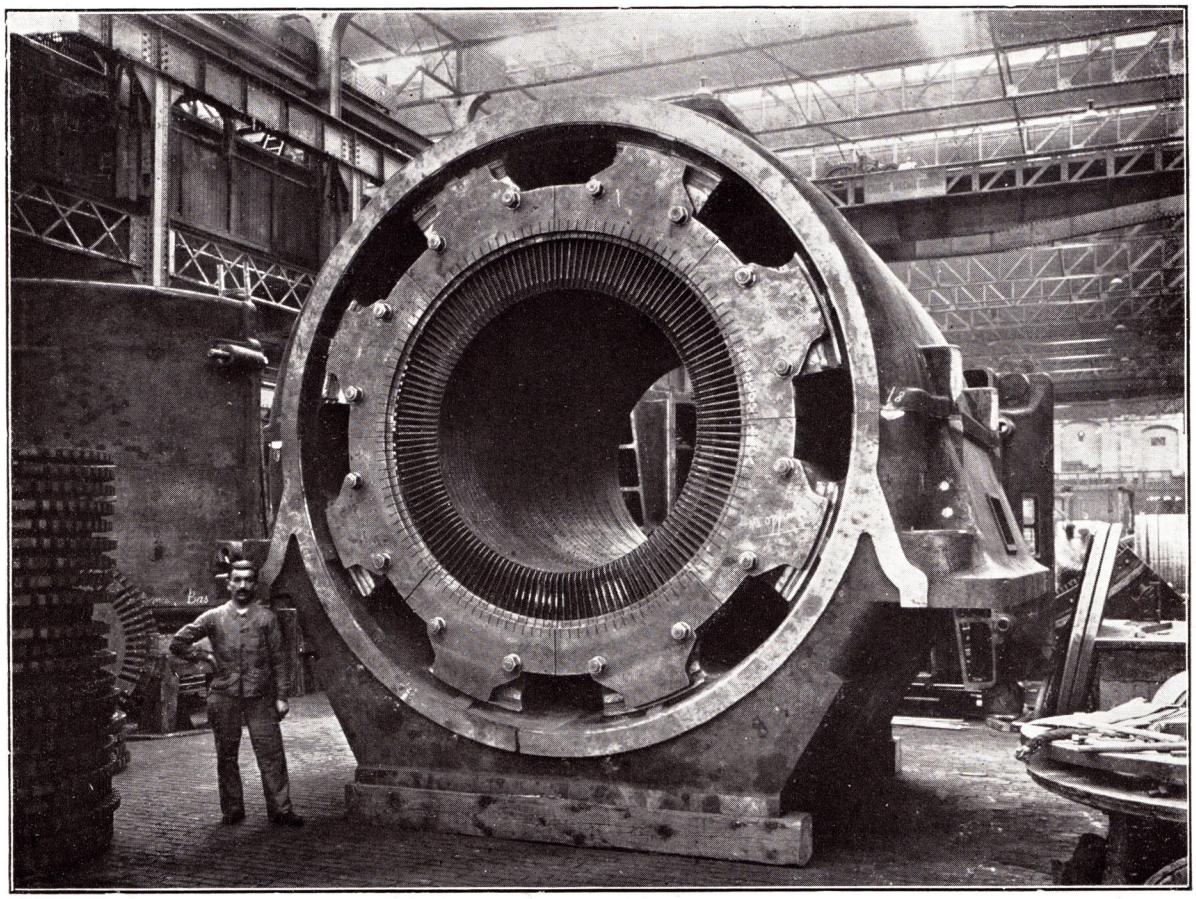


Fig. 32. — 40 000 kw Generator — Stator — View taken at the factory.

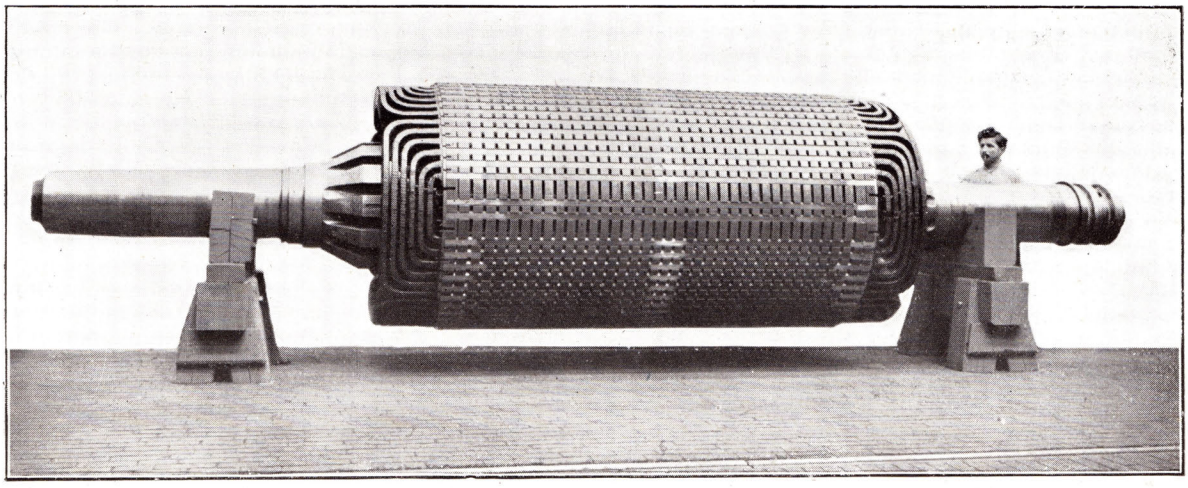


Fig. 33. — 40 000 kw Generator — Rotor — View taken at the factory.

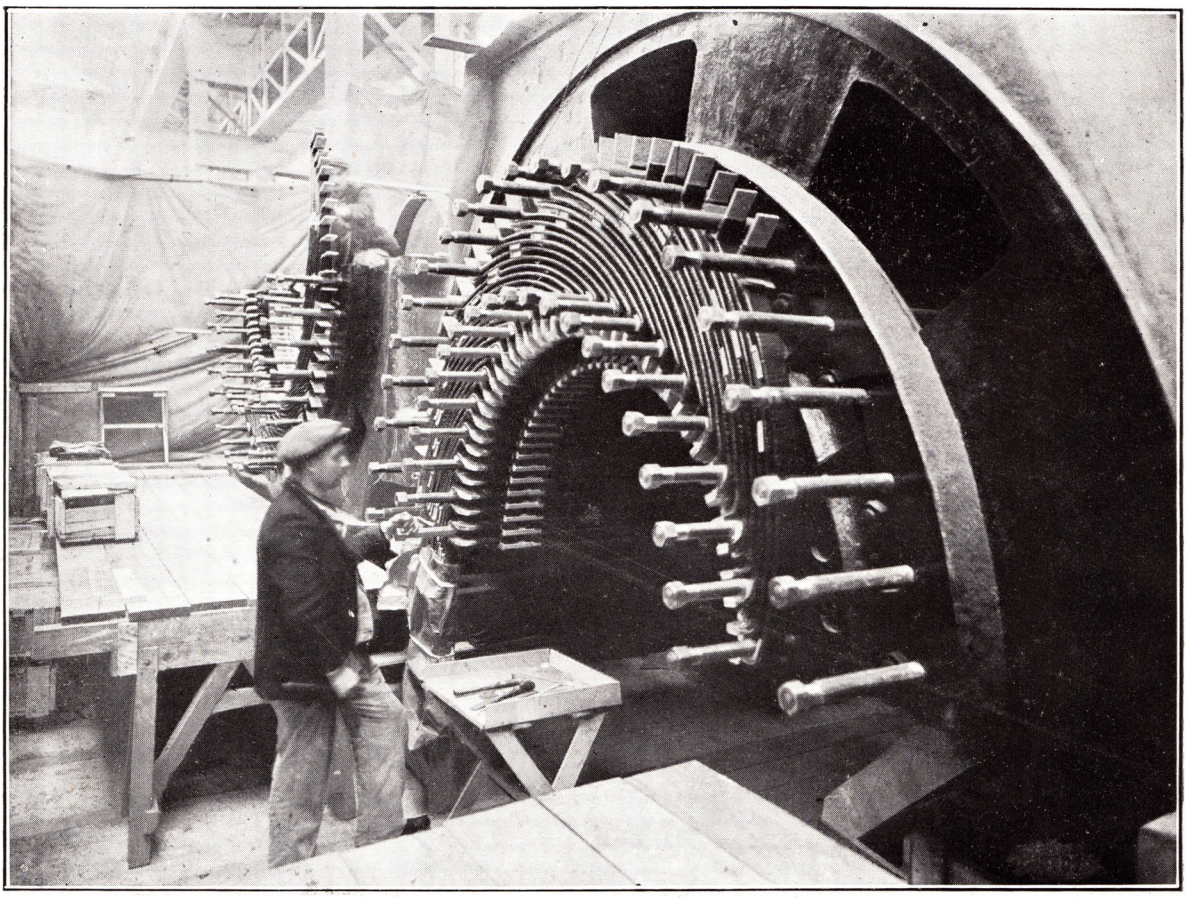


Fig. 34. — 40 000 kw Generator — Winding the Stator.

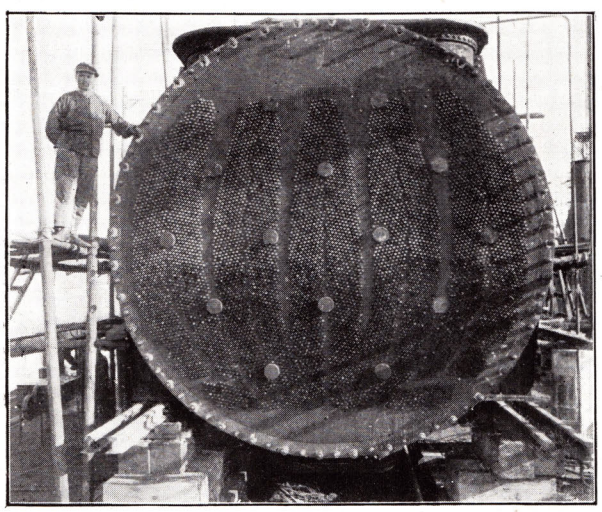


Fig. 35.

Condenser. — View taken during construction.

Guaranteed Steam Consumption upon which the penalties and premiums are based (without extraction of low pressure steam).

Full load	4,37 kgs.	per kw. hour
3/4 load	4,3	— —
1/2 load	4,5	— —
1/4 load	5	— —

The extraction of steam produces a reduction of approximately 4 0/0 in the coal consumption.

Condensers (1) :

Tubular surface.....	3 500 sq. m.
Centrifugal circulating pumps (two per condenser).	
hourly capacity	6 750 sq. m.

(1) All condensers are identical, they have been furnished by the Société des Condenseurs Delas, 103, rue Saint-Lazare, Paris. The Société Rateau, 40, rue du Colisée, Paris, have furnished the pumps and their accessories. The Chantiers Navals Français, 33, rue Mogador, Paris, have built the main condensers.

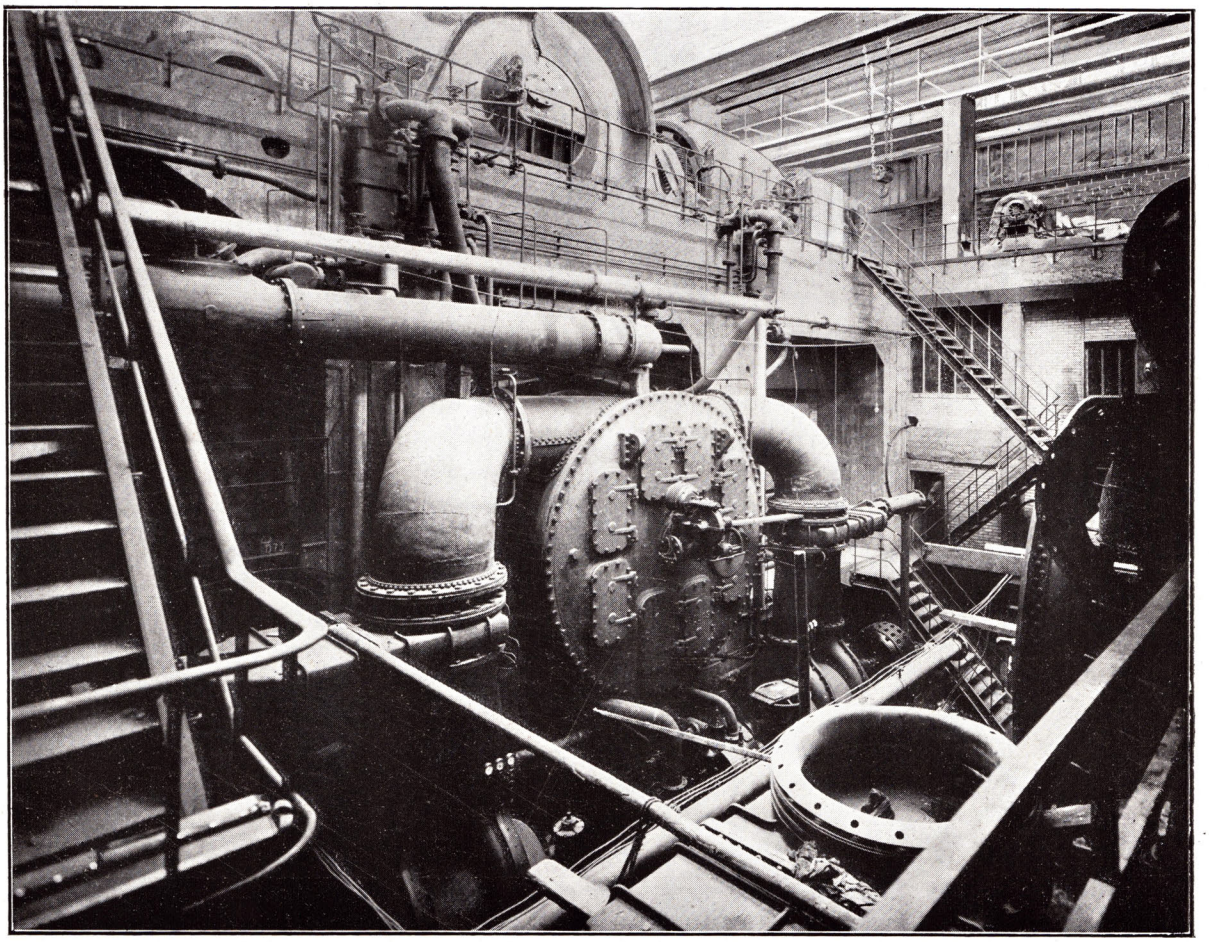


Fig. 36. — View of the pumps mounted under the main floor of the Generating Room.

Each pump is driven by a 3-phase induction motor direct connected. One pump of each group is equipped with a steam turbine for emergency use.

Condensate water pumps : two independent pumps with electric motor for each unit ; each one having a capacity of 200 cubic meters per hour.

The air extractors are steam operated ejectors ; there are two main ejectors and a special starting ejector.

The guaranteed vacuum with circulating water at a temperature of 15° is 96,5 o /o.

Cooling Air. — The cooling system of the generators is of the closed air-circuit type, that is, the same air circulates in the same machine, the air being cooled by a tubular cooler in which the condensate flows.

The advantages of the system are the recuperation of the heat, the suppression of dust and lessening of the firehazard in case of short circuit. A special apparatus is provided for increasing the nitrogen content in the cooling air to such an extent that it will not support combustion.

An auxiliary source of filtered air has been provided in case the usual air cooling system is out of commission. The air-filter has sufficient capacity for supplying air for four machines operating at full load.

Auxiliary Turbo-Alternators. — Two turbo-alternator sets are provided to furnish power to the auxiliaries (1).

Power each unit	3 000 kw.
Revolutions.....	3 000 rmp.
Tension	3 000 volts.

(1) These sets have been furnished by the Société Rateau.

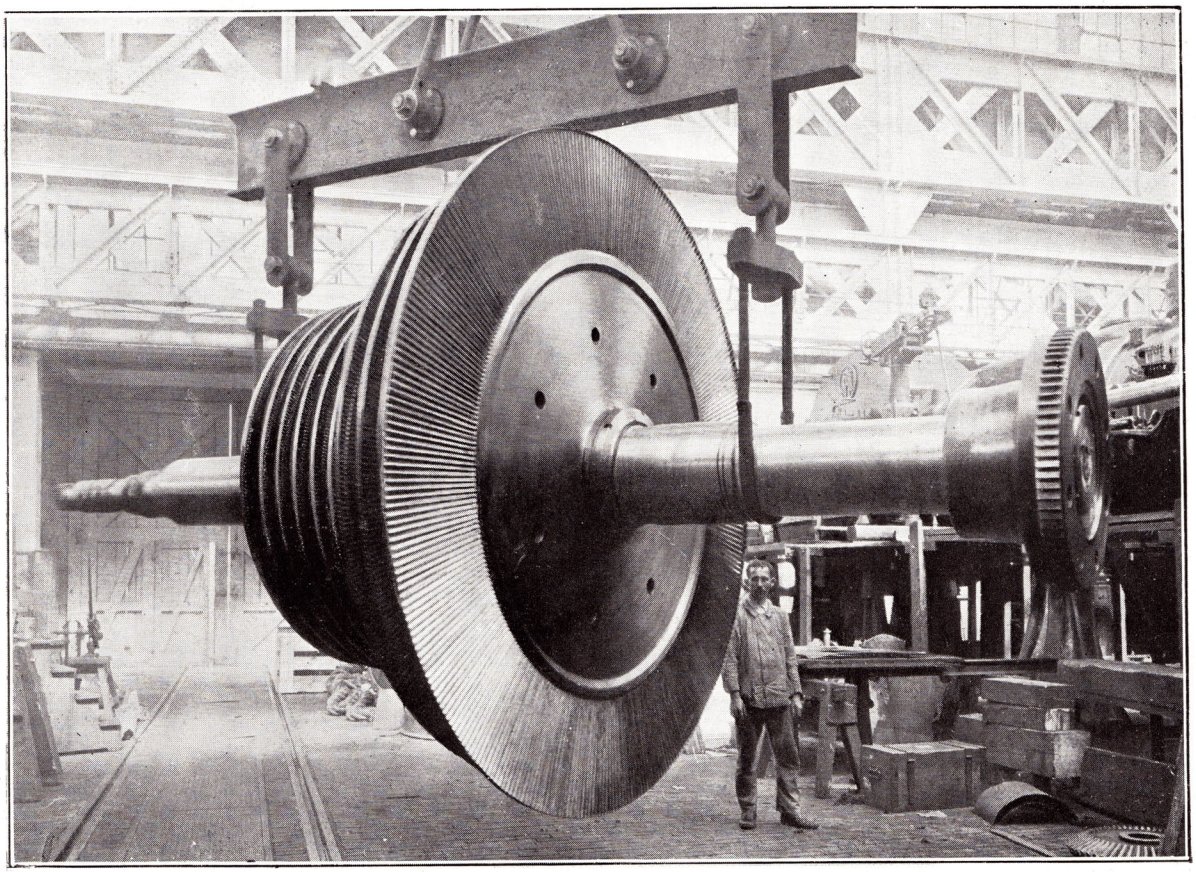


Fig. 37. — Rotor of 40 000 kw Steam Turbine — View taken at the factory.

Driving the auxiliaries. — Electric motors are used for the normal operation of the auxiliaries.

The general distribution of power for the auxiliaries is at 3 000 volts, and all motors of 50 H. P. or over are wound for 3 000 volt operation.

A. C. motors below 50 H.P. are wound for 220 volt operation.

The motors driving the chain-grates and boiler-room fans, as well as those used for the apparatus necessary for overhauling and maintenance, are wound for 500 volt D. C. operation.

A sufficient number of the principal auxiliaries are provided for emergency operation by auxiliary steam turbines.

The necessary power for the auxiliaries is supplied normally from the main station bus-bars by means of step down transformers, but can be furnished from the auxiliary turbo-generators.

The direct current is furnished by rotary converters with a storage battery floating on the line.

Emergency excitation for the main generators can be furnished either by the storage battery or by auxiliary exciters, each auxiliary exciter being of the same rating as the direct connected exciter.

Steam Piping. — The main steam leads are formed from sections of seamless steel pipe, having an inside diameter of 254 mm., and provided with flanges acetylene-welded to the pipe body. (1).

Each boiler is piped directly to a steam separator. Each separator is provided with two sets of outlets, one set (2 pipes of 254 mm. inside diameter) leading direct to the steam inlet of the turbine, the other set being connected to the longitudinal steam mains (2 pipes of 254 mm. inside diameter).

All the piping and valves are installed on a

(1) The piping has been furnished by Aiton and Co. Ltd., Derby (England) and by the Etablissements Ladreyt, 182, boulevard Victor-Hugo, Clichy (Seine).

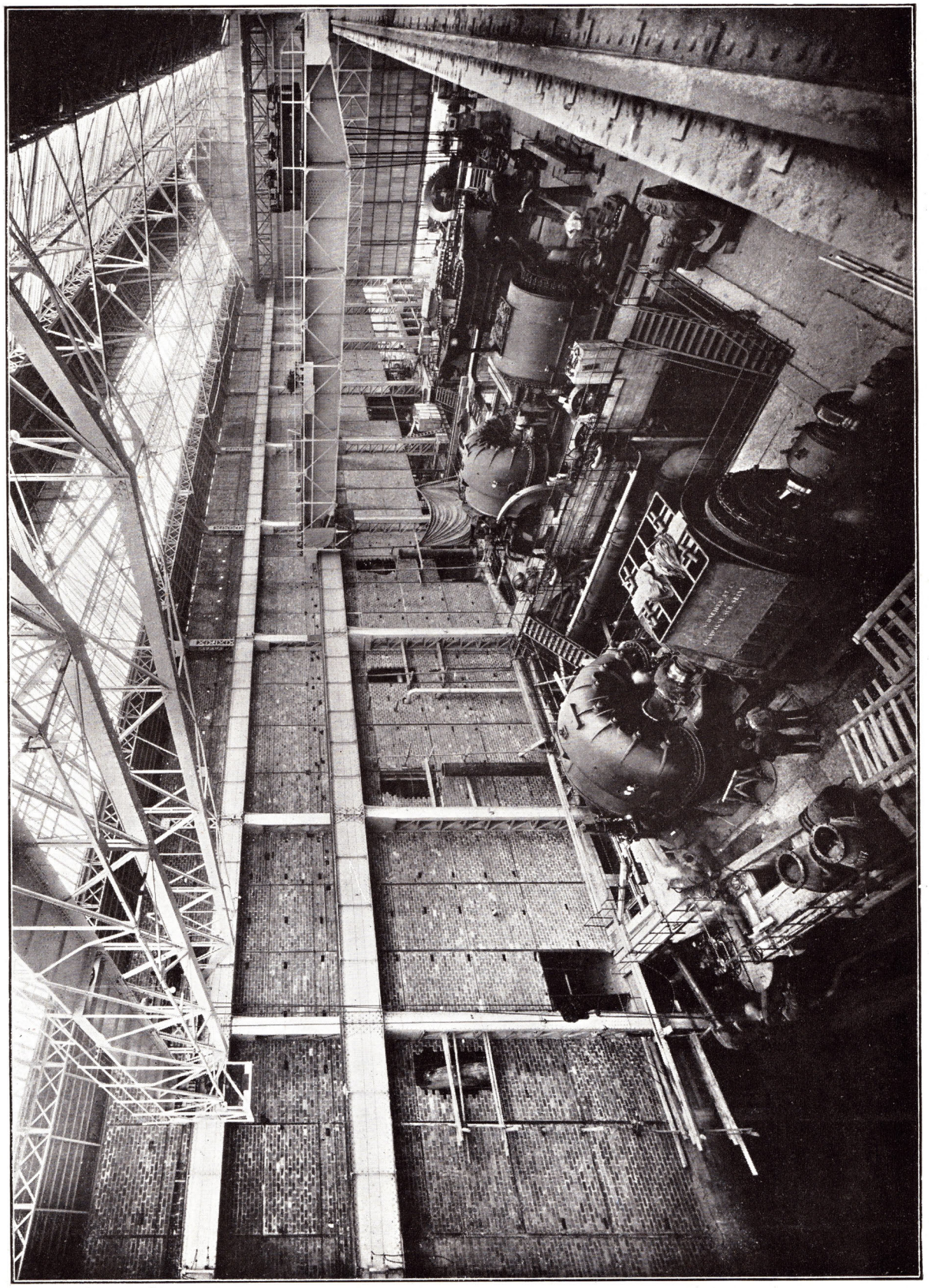


Fig. 38. — The Main Generating Room — View taken from the North-West Corner of the Building (February 1921).

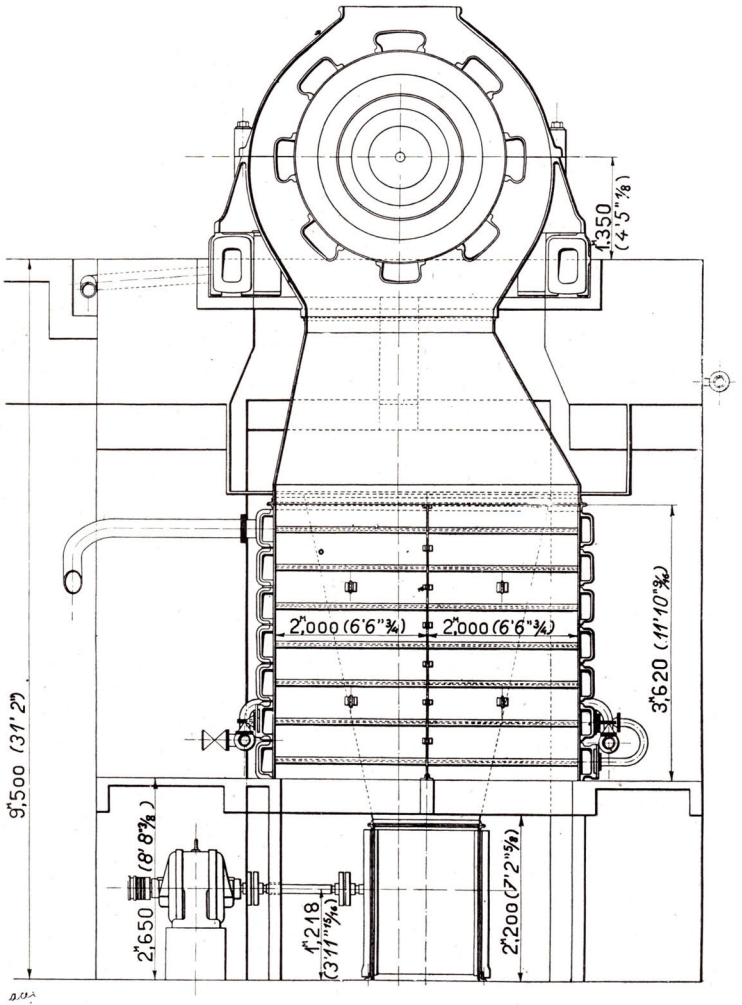


Fig. 39. — 40 000 kw Turbo-Generator. Section through Generator.

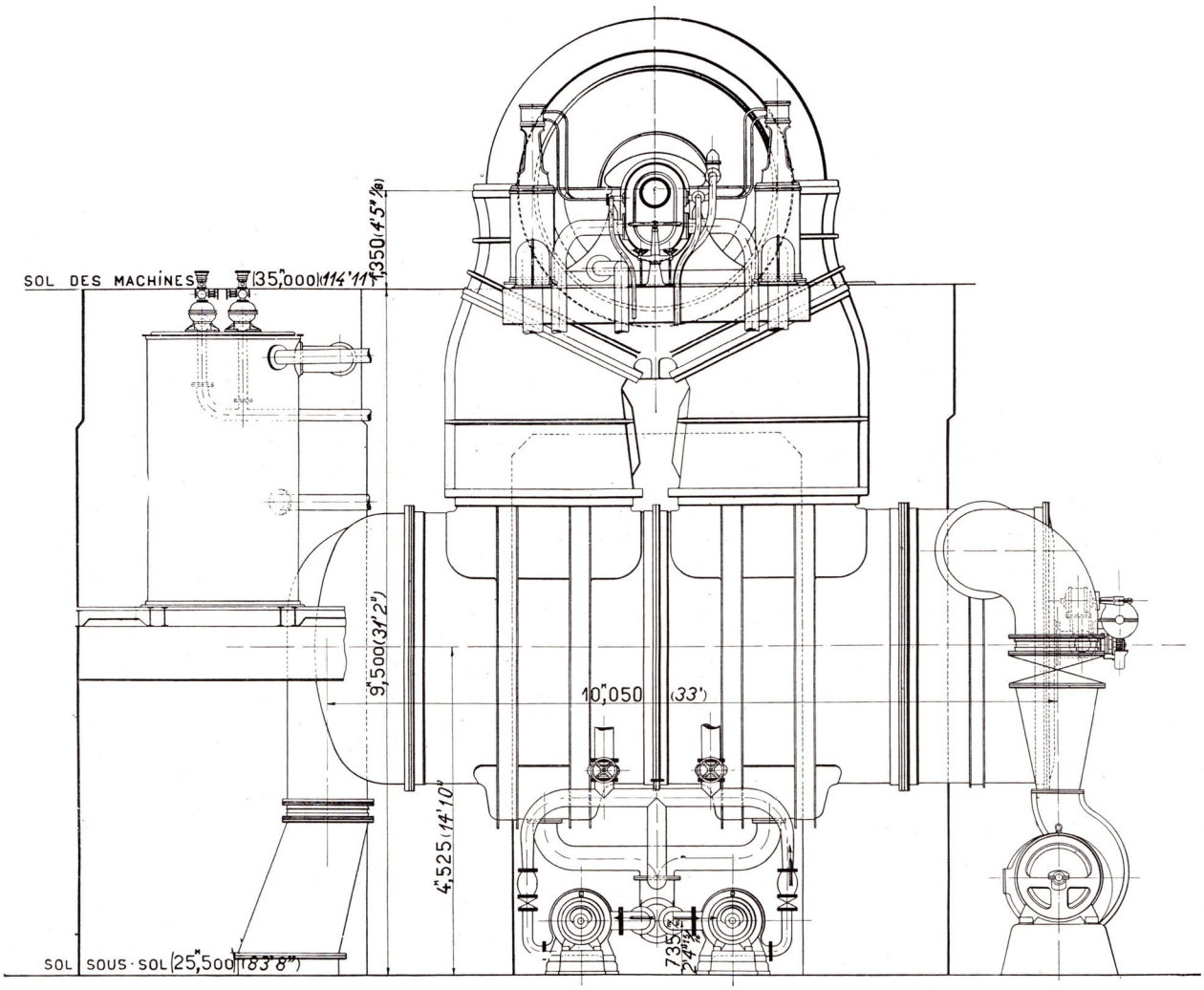
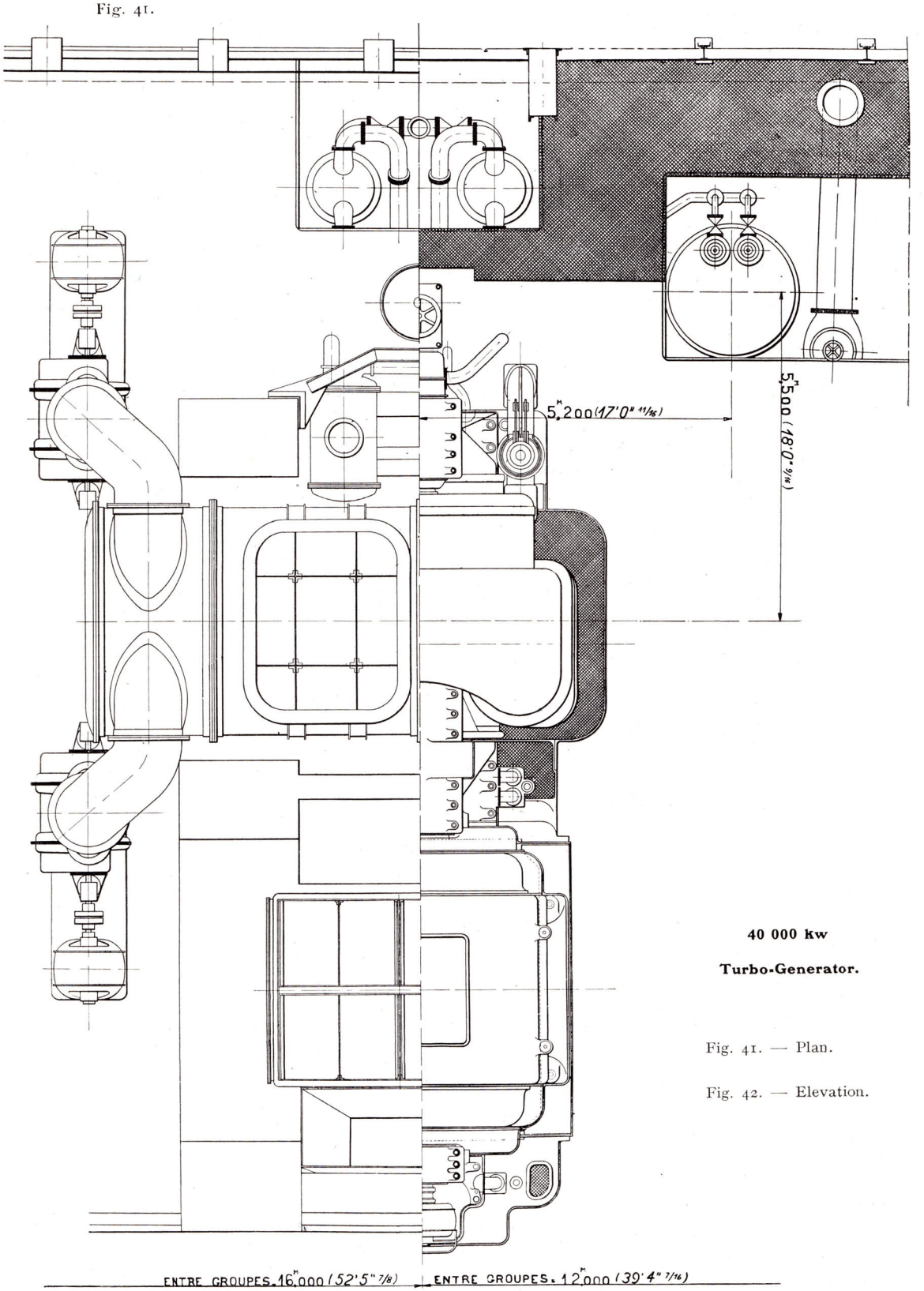


Fig. 40. — 40 000 kw Turbo-Generator — View of turbine end.

Fig. 41.



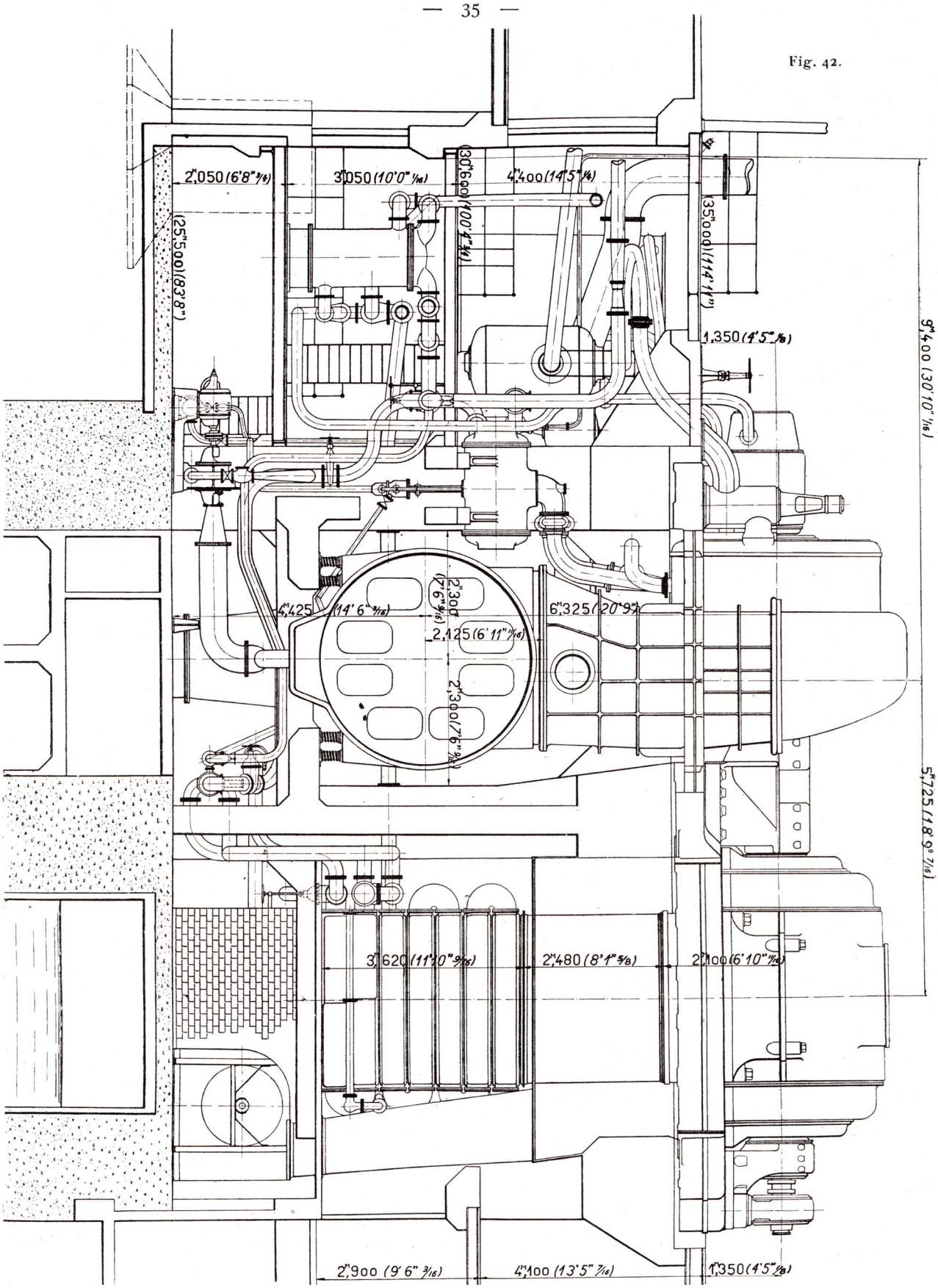
40 000 kw

Turbo-Generator.

Fig. 41. — Plan.

Fig. 42. — Elevation.

Fig. 42.


2",050 (6'8" 7/16)
3",050 (10'0" 1/16)
4",400 (14'5" 1/16)
30",600 (100'4" 1/16)
35",000 (114'11")
(25",500 (83'8")
1,350 (4'5" 1/8)
9",400 (30'10" 1/16)
2",300 (7'6" 9/16)
4",425 (14'6" 3/16)
2,125 (6'11" 7/16)
6",325 (20'9")
2",300 (7'6" 9/16)
5",725 (18'9" 7/16)
3",620 (11'10" 9/16)
2",480 (8'1" 5/8)
2",100 (6'10" 7/16)
2",900 (9'6" 3/16)
4",100 (13'5" 7/16)
1",350 (4'5" 1/8)

special intermediary deck located between the boiler room floor and the basement. The operating mechanisms are all controlled from the boiler room floor, where they are grouped upon diagramatic control boards. In case of accident, these mechanisms can be operated without danger to personnel from escaping steam.

General Water Supply. — This system includes *a)* the supply and general distribution of water for the station (cooling water for the transformers, general cleaning, fire protection, etc.).

The supply is taken from the cooling water intake canal through three intakes, each intake serving a pump of 250 ton capacity. Two of the pumps are motor driven, the third being operated by steam. The three pumps discharge through a common main into two large filter basins. The filtered water drains into two cisterns, each of 84 cubic meters capacity. A battery of motor driven pumps lifts the water from the two cisterns into a storage reservoir of 330 cubic meters capacity. From the storage reservoir the water is fed directly into the service mains, and also, to a pump for purifying water by the hot chemical process (1), capable of treating 60 to 120 cubic meters of water per hour.

The purified water is discharged into a storage tank, and from there is fed to and converted into steam by two Babcock boilers, specially designed for this service.

b) The system of handling the condensate is as follows :

From each main condenser, the condensate is circulated through the main generator air coolers, and from there, is led to the preheaters, which are operated by extracted steam. At the outlet of the preheater the water has been preheated to 90° C. if the group is operating at full load, or to 75° C. if operating at half-load.

The condensate is then discharged into a hot well of 123 cubic meters capacity (three hot wells are installed having a total capacity of 369 metric tons). Into the hot wells exhaust the main boiler feed pumps, the turbine driven auxiliaries and, if necessary, extracted steam from the 3 000 Kw. auxiliary turbo generator sets. The temperature of the water is thus increased to 100° C.

The condensate then passes from the hot wells through degassers (4 of 200 ton capacity and 2 of 50 ton) operating under the Paul Kestner system (1), where all traces of dissolved oxygen and carbonic acid gas are removed. The water is then pumped into the economizers by the main boiler feed pumps.

There are nine boiler feed pumps provided, six having a capacity of 225 cubic meters per hour against a pressure of 30 kilograms par square centimeter (2) and driven by 420 HP motors, and three of the same capacity driven by steam turbines (3).

From the settling drum of each boiler a certain quantity of water is continuously passed back into the hot well, in order to maintain the salt content of the boiler water at a minimum.

Fire protection. — A central fire main with a series of branches and connections has been installed. The fire main can be fed either from the storage reservoir or by a special pump drawing water directly from the main water intake.

Cleaning. — A special main has also been provided for furnishing water for general cleaning purposes. A second main, fed by a special pump, is also provided for furnishing water for cleaning the condensers. The condenser shells are provided with a special device, patented by the Société Alsacienne, which permits the cleaning of the interior of the tubes by means of water jets without removing the condenser from service.

A vacuum line and necessary pump has also been provided, permitting the removal of dust and cleaning any part of the station by the vacuum method.

Oil Service.

a) The oil service is located in a separate building at a distance from the main station. The building is divided into separate rooms which contain the following :

Store room, with necessary oil storage tanks and

(1) This apparatus, Kestner system, has been furnished by the Union Electrique.

(1) Furnished by the Union Thermique.

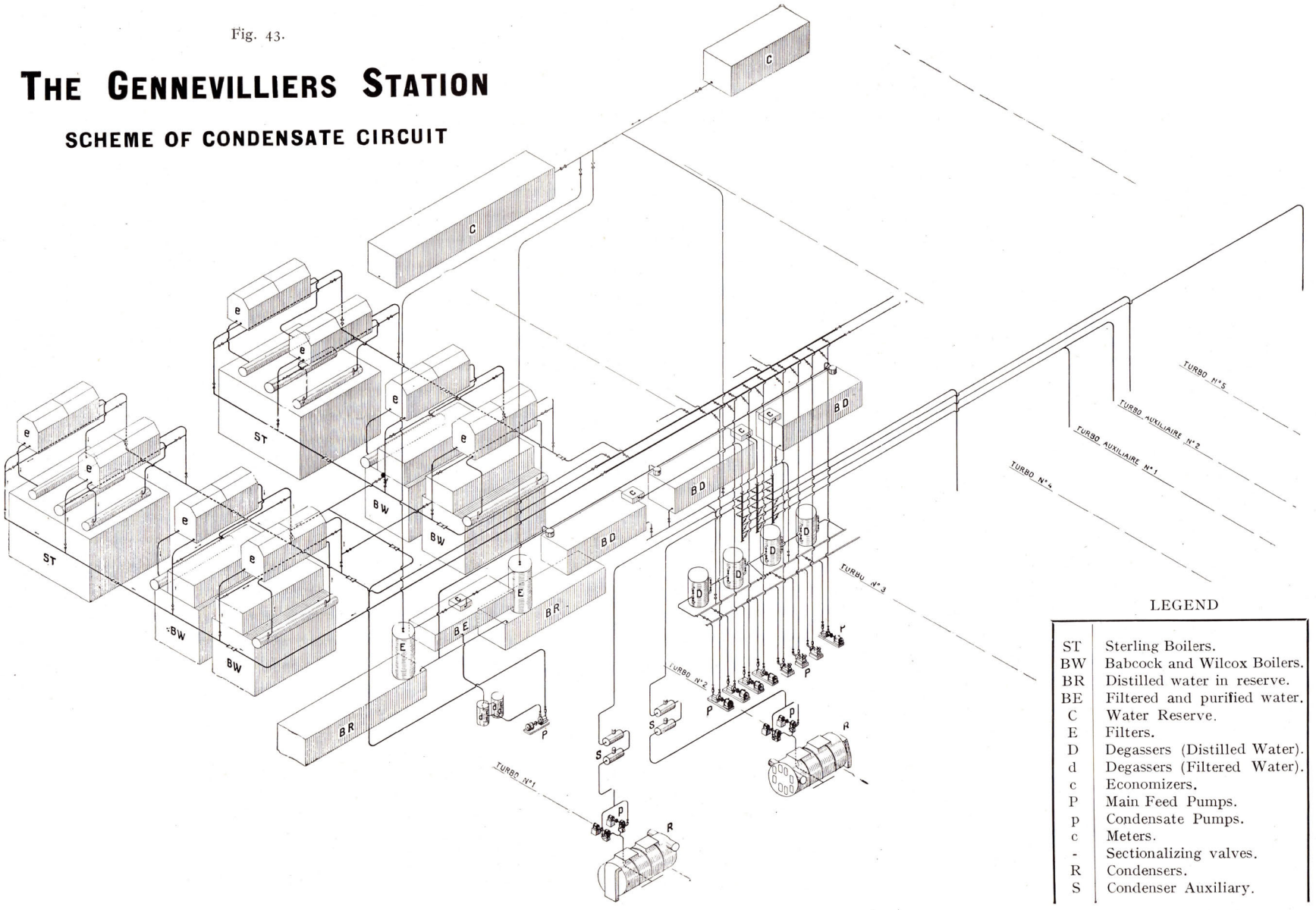
(2) Five Sulzer Pumps have been furnished by the Compagnie de Constructions Mécaniques, 12, rue Boissy-d'Anglas, Paris, and the other pump built by the Maison Beaudrey-Bergeron.

(3) Constructor : G. and J. Weir, Glasgow (England).

Fig. 43.

THE GENNEVILLIERS STATION

SCHEME OF CONDENSATE CIRCUIT



LEGEND

ST	Sterling Boilers.
BW	Babcock and Wilcox Boilers.
BR	Distilled water in reserve.
BE	Filtered and purified water.
C	Water Reserve.
E	Filters.
D	Degassers (Distilled Water).
d	Degassers (Filtered Water).
c	Economizers.
P	Main Feed Pumps.
p	Condensate Pumps.
c	Meters.
-	Sectionalizing valves.
R	Condensers.
S	Condenser Auxiliary.

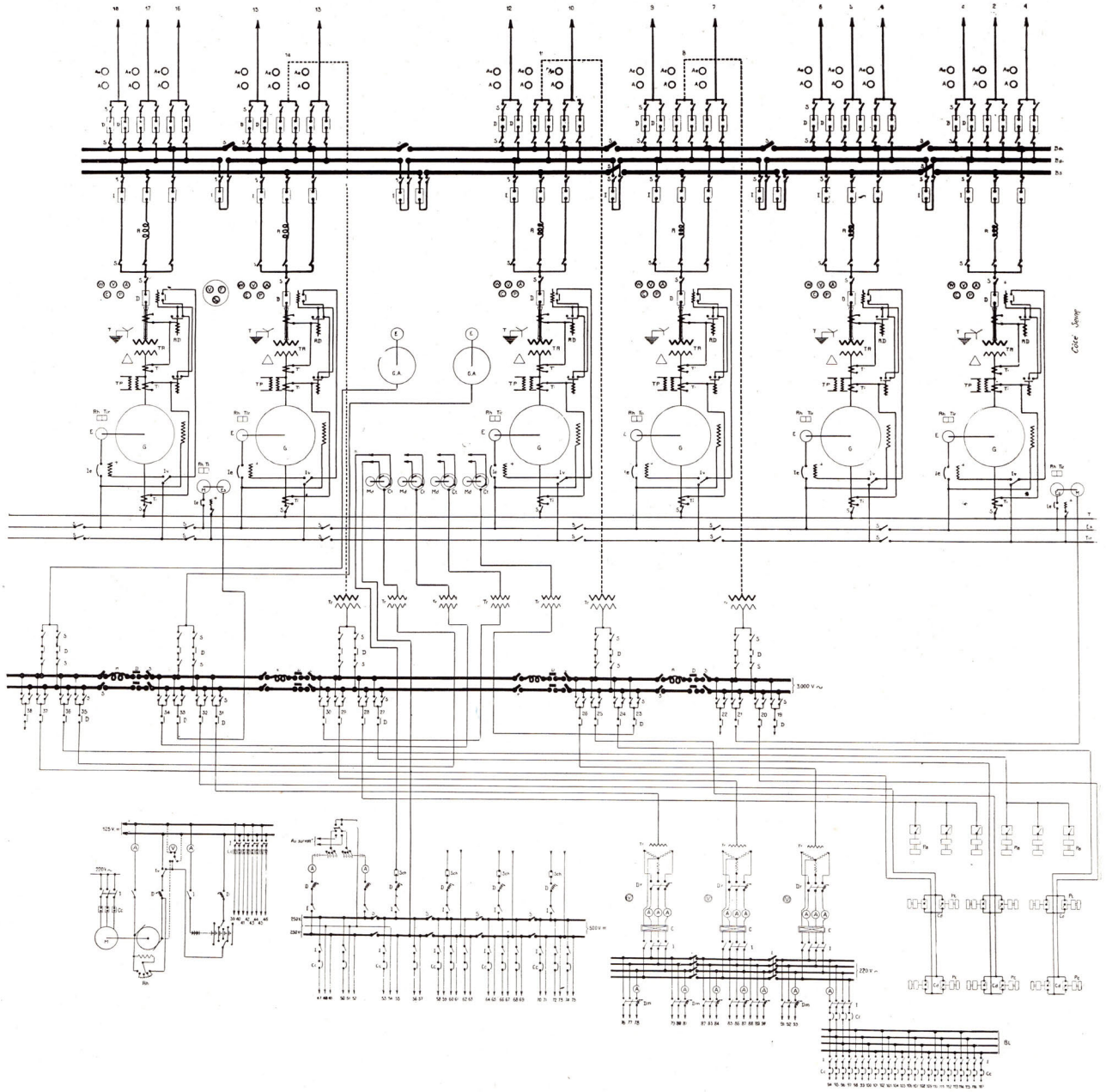


Fig. 44. — Wiring Diagram of Station.

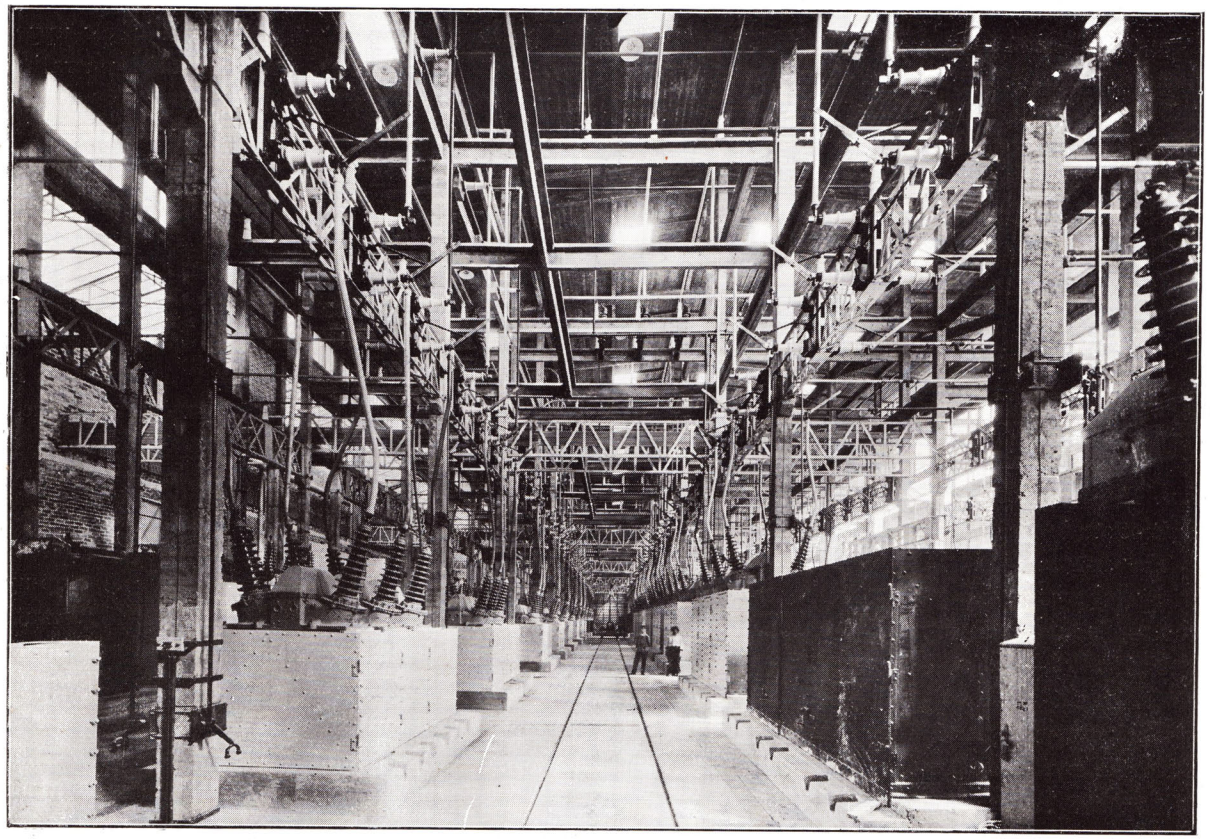


Fig. 45.

Interior of the High Tension Switch House (View taken from Northern End).

pumping apparatus for filling and emptying the tanks.

Apparatus for the treatment of the used oil,

Oil filters and heaters for drying and preparing transil oil,

Necessary pumps for oil distribution.

b) A system with necessary piping which permits the handling mechanically of the oil, both lubricating and transil. A separate set of piping is used for transporting the clean oil distinct from the used.

Switch Gear.

a) Apparatus for 60 000 volts.

From an electrical point of view, the station is divided into sections equal to and corresponding to the number of units installed, each section comprising the following :

One main oil circuit breaker ;

Three sets of disconnecting switches permitting the unit to be placed on either of the three sets of bus bars ;

Six sets of feeder disconnecting switches, two sets for each feeder due to the use of two oil circuit breakers ;

Three current limiting reactances, separating the different sections of the bus bars ;

One oil circuit breaker for sectionalizing the different sections of the bus.

Except for the auxiliary, all the oil circuit breakers are of the same type having a normal rupturing capacity of 600 000 kw. They are of the General

Electric Company design, manufactured by the Compagnie Française Thomson-Houston.

The oil circuit breakers are of the automatic type, but are not arranged to open under overload, the generators having been designed to withstand full short circuit at normal excitation. A system of differential relay protection is provided to trip the oil circuit breaker in case of a fault within the generator or its set of step-up transformers.

The feeder oil circuit breakers are also arranged as above with differential relay protection for the cables.

Each oil circuit breaker is installed in a three cell reinforced concrete compartment, of sufficient size to hold the entire quantity of oil. A drainage system is provided to withdraw the oil in case of fire. The entire compartment is further enclosed in a sheet steel case of 8 mm. thickness.

The current limiting reactors (1) are enclosed within copper cylinders, having bronze bases and covers, located one upon the other, and rigidly bolted into place. The reactors are oil immerged and are held rigidly in position, yet with a sufficient elasticity, by means of bronze bolts provided with Belleville spring washers.

A special bus is provided for feeder testing.

All of the switch gear is of the outdoor type and the conductor spacing has been made the same as that for an outdoor installation. However, to facilitate the upkeep, the whole apparatus has been enclosed in a remarkably light housing of reinforced concrete, amply provided with ventilators.

An observation gallery has been installed extending entirely around the Building, permitting the easy access to each insulator and conductor.

Standard gauge tracks connecting with the station railway system have been provided in the three principal bays.

b) Low Tension Switchgear.

The low tension switchboards and switch gear have been centralized in a large building extending the length of the generating room, and located between the latter and the building housing the high tension apparatus.

(1) The instruments of this switchboard are mainly furnished by the Compagnie Française Thomson-Houston.

The building is divided into three floors, the first floor containing the laboratories and the cells for the step-down transformers, the second housing the 3 000 volt apparatus, and the third or upper floor, which is separated from the main generating room by a glass partition, containing the switchboards. Upon the switchboards are mounted the meters and instruments and the control buttons for operating and controlling the 60 000 and 3 000 volt circuits, as well as the distribution boards for the 500 volt direct current and the 220 volt alternating current circuits for the small auxiliary motors and the station lighting (1).

In laying out the above, simplicity was kept in mind, and, to facilitate operation and maintenance, the apparatus was grouped schematically.

Upon the third floor are also located the office of the load dispatcher.

Transformer. — The 6 000-6 0000 volt step-up transformers (2) are enclosed in a series of separate cells, located in the main generating room and upon the side adjacent to the switch gear.

Each cell is built with a structural steel frame and with walls of reinforced concrete. A ventilating opening is provided for the escape of fumes and smoke in case of fire.

Under each cell is located an individual reservoir of sufficient capacity to hold the quantity of oil in its transformer.

An observation corridor extends the length of the cells and along the corridor are located the thermometers, valves for regulating the cooling water flow, oil level indicators, etc.

The hand operated switches for grounding the neutral points are also located along the corridor.

Laboratories. — There has been provided laboratories for the making of mechanical tests upon materials, coal and oil analysis, as well as one equipped for making high potential tests.

The electrical laboratory is provided with a 6 000 kva. motor generator set and testing

(1) The apparatus of these switchboards are furnished by Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.

(2) The transformers were furnished by the Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.

transformer for feeder testing up to twice normal voltage (1).

Repair shop. — A repair shop of 300 square meters floor space has been provided and equipped for making all repairs.

In an annex is provided an electrically heated drying and baking oven for the electrical material. This oven is of sufficient size to accomodate a main alternator revolving field. A smaller oven will be installed at a later date in the main repair room for use in the repair of small transformers and motors.

A blacksmith shop of 600 square meters floor space has also been provided.

The shops are separated by a standard gauge siding, connecting with the main station railway system.

Travelling cranes. — The installation of travelling cranes has been designed to facilitate the handling of the large machinery without interrupting the operation of other machinery.

Fig. 46. — General View taken from the railway bridge (December 1920).

The generating room has been provided with two travelling cranes operating at different levels, the upper crane having a capacity of 100 tons, the lower 20 tons.

For handling the transformers a separate 40 ton travelling crane has been provided, capable of lifting the transformers from their pits without disassembling or draining.

The repair shops are equipped with one 60 ton and two 15 ton travelling cranes.

(1) These apparatus have been specially designed and built by the Société Oerlikon, 15, rue de Milan, Paris.

The boiler room is equipped with a 10 ton travelling crane, which can load or unload material directly from the cars on the boiler room siding.

Coal handling (1).

a) From Barges. — Two unloading bridge cranes are provided, each equipped with a travelling pivoted unloading arm, a travelling hopper and a double belt conveyor, which permit the following procedure.

1° Unload coal from barges (200 tons per hour per unit) for delivery either to the storage yard or direct to the boiler house.

2° Retake coal from storage and transport same to the boiler house (200 tons per hour per unit).

For the delivery of the fuel to the boiler house, the belt conveyors of the unloading bridge discharge into motor driven dumping cars ; each car having a capacity of 20 tons of coal and running on a track. The dumping cars discharge the coal into fixed bins, which in turn feed two bucket elevators.

The two bucket elevators have each a capacity of 200 tons per hour. They are fed by metallic travelling belts, each belt receiving its charge from two reinforced concrete bins. These bins can be filled either from the motor driven dumping cars, from the railroad cars direct, or from auxiliary motor operated cars which collect the fine coal which has fallen through the gratings.

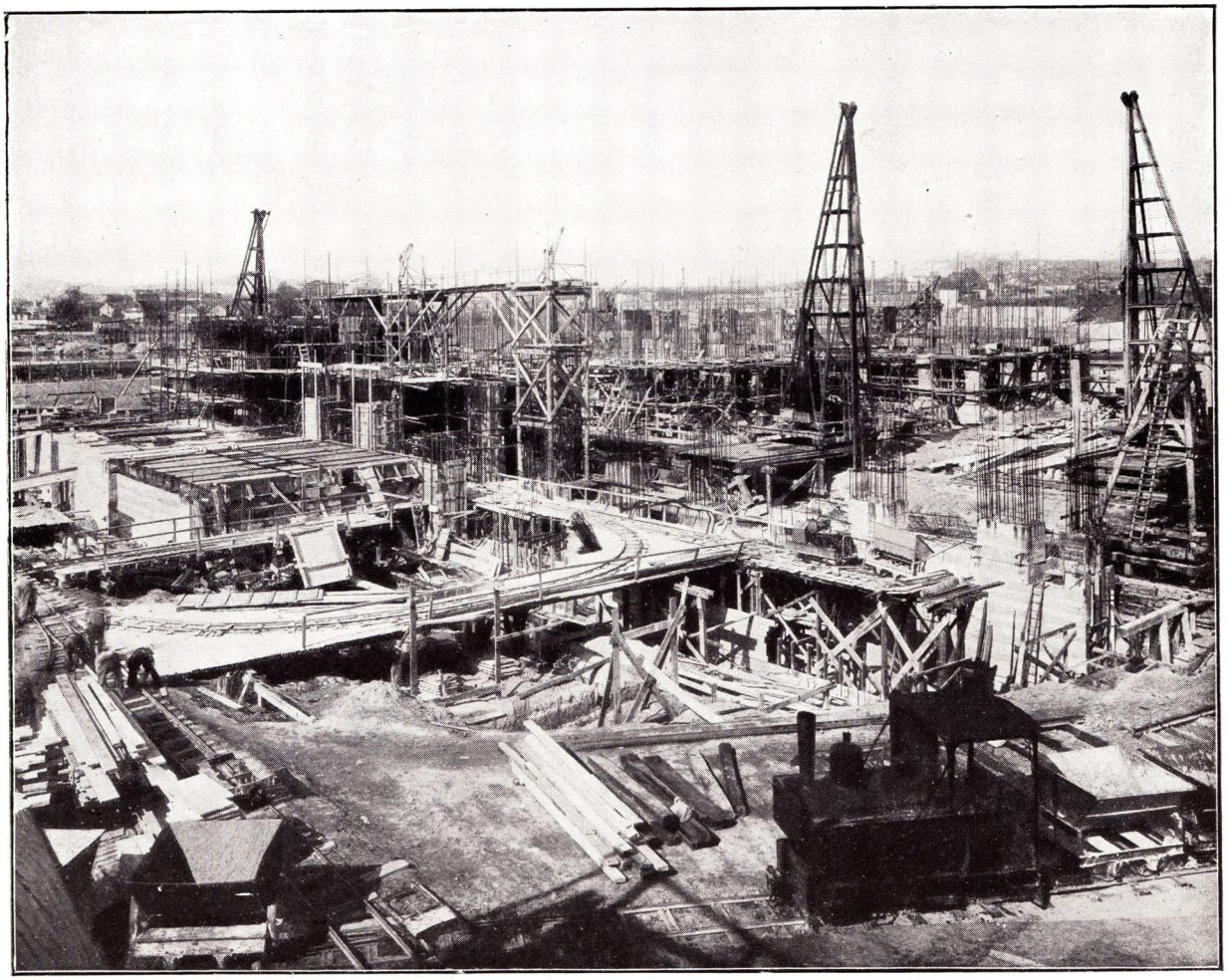


Fig. 47. — General View taken from the top of embankment (March 1921).

(1) The constructor of coal handling apparatus is the Société de Construction et de Location d'Appareils de Levage et de Matériel de Travaux Publics, 78, rue de Vitruve, Paris.

The bucket elevators discharge into a fixed bin from which the monorail distributing cars, each of 2 ton capacity, are charged. The monorail cars serve the individual boiler hoppers.

The total capacity of the boiler coal hoppers is 3 800 tons.

have been installed at convenient points on the two sidings.

Soot and ash handling. — Each boiler is provided with air nozzles (1) installed among the tubes and in the economizers and preheaters. These air nozzles permit the blowing out of soot by compressed air,

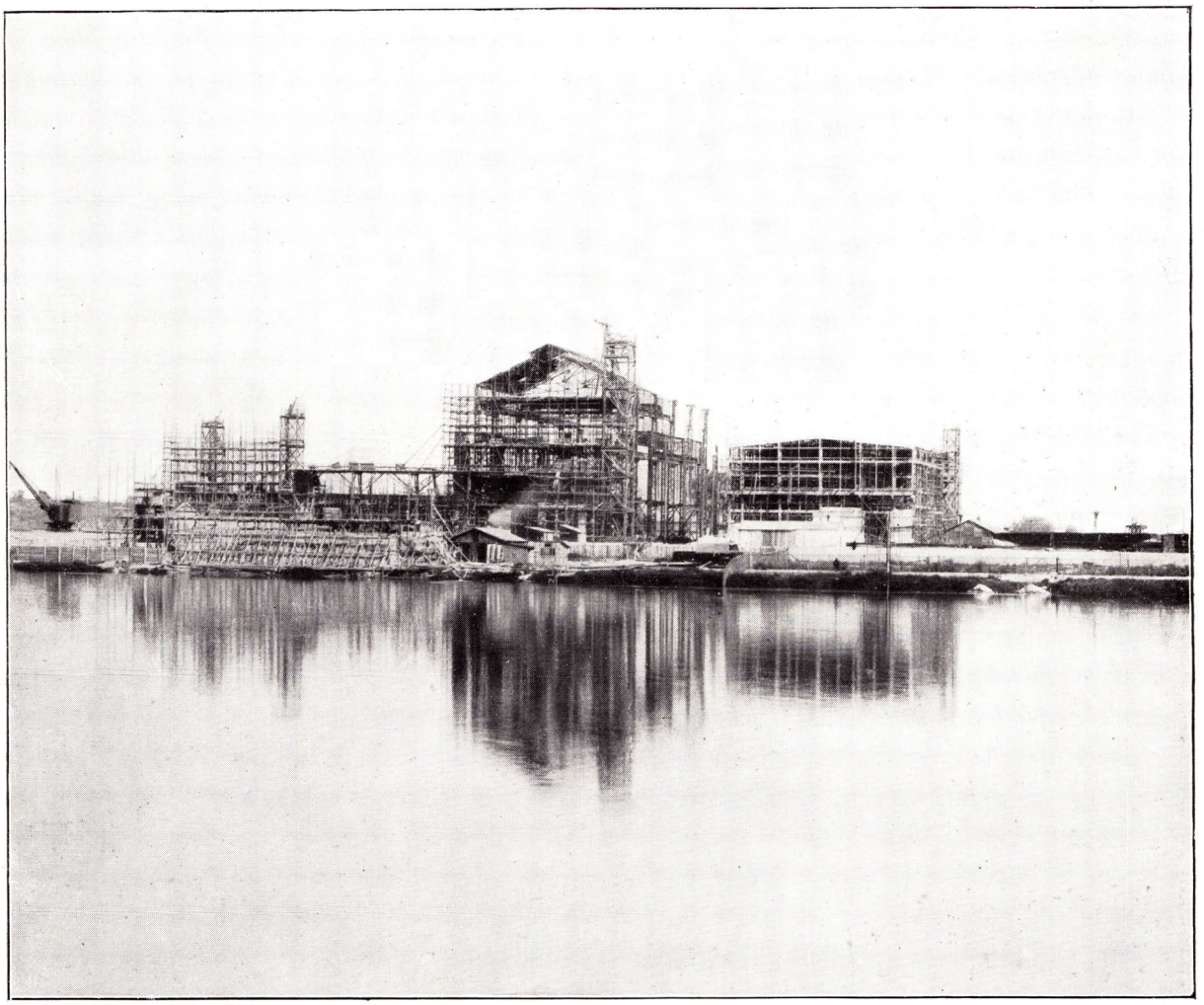


Fig. 48. — General View taken from the Seine (June 1921).

b) By rail. — As stated above, the railroad cars can be discharged directly into the chain elevator bins.

On the other hand, two railroad sidings extend the entire length of the storage yard from North to South, permitting the unloading of the railroad cars directly into pits, from which the coal is gathered by the bridge cranes and stacked into piles to an average height of 8 meters. Tilting platforms

the soot being collected in metallic hoppers which may be emptied directly into cars.

Each boiler and economizer is provided with steam blowers for cleaning the stack (2).

The ashes are collected by storage battery cars,

(1) Manufacturer : Office Technique et Industriel du Centre, 16, rue André-Moinier, Clermont-Ferrand (Puy-de-Dôme).

(2) Manufacturer : Diamond Power Specialty Co., Detroit, U. S. A.

each of 40 ton capacity and operating on standard gauge tracks. The cars are emptied by a tilting elevator into a storage bin, from which they can be loaded for transportation either by rail or water.

For about one year, the ashes will be used for filling and grading the yard around the station.

leading directly to the main generating room and to the building in which the main switchboard is installed.

Particular care has been taken in the design of the buildings reserved for the workmen. These buildings are provided with locker-rooms, shower and bath rooms, a dispensary, a dining-hall, etc.

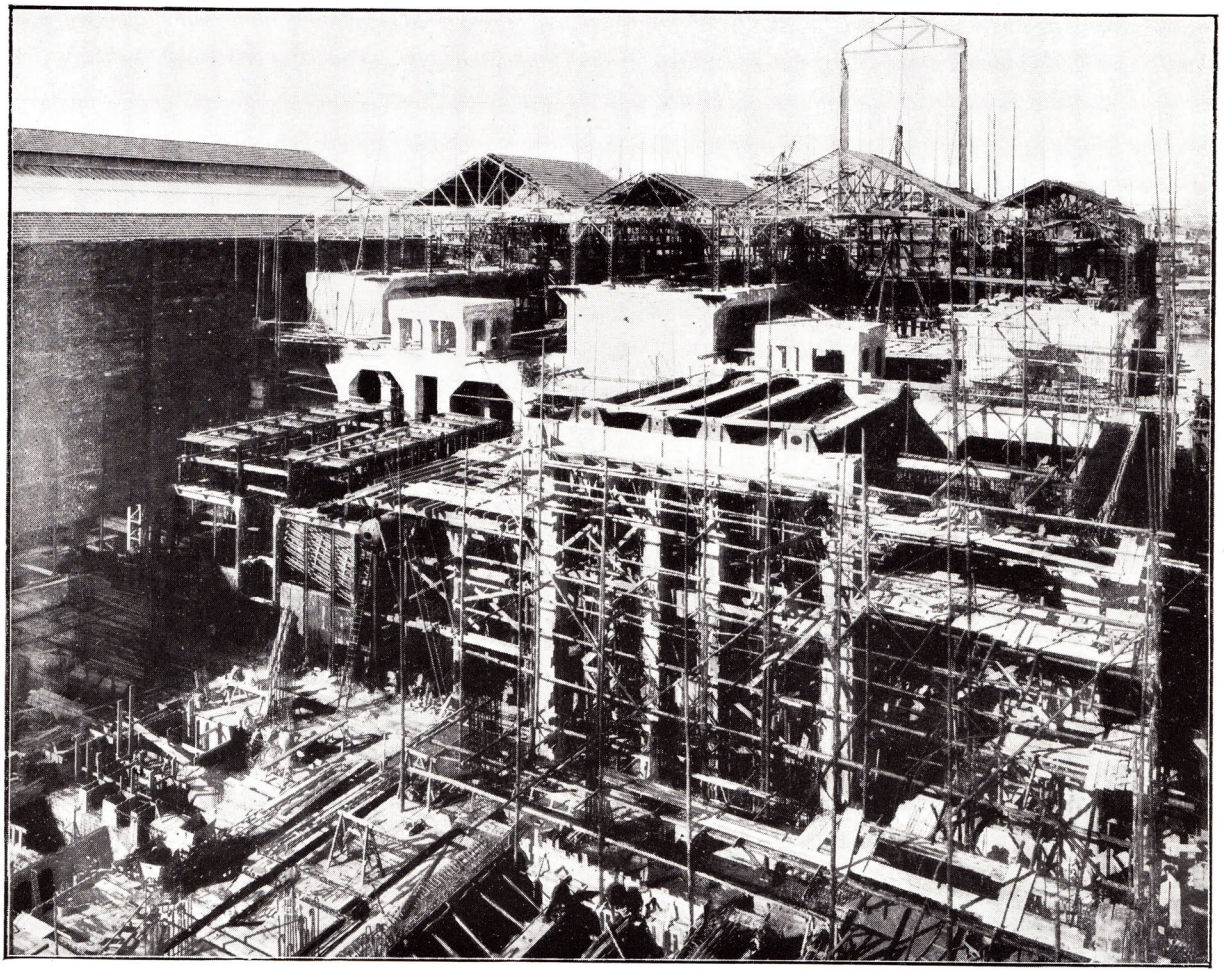


Fig. 49. — Construction of the Boiler House (October 1921). The erection of the boilers being made at the same time as the building.

At the end of that period, they will be used in the manufacture of briquettes.

An installation is being investigated that will extract the particles of coke remaining in the ashes.

Offices and housing of personnel. — A separate office building has been erected for the management, the accounting and engineering departments. This building is provided with passages

Particular care was given to the maintenance of sanitary conditions in their lay-out.

Apartments have been provided for the principal personnel of the managing and engineering departments, as well as, for the main foremen.

All of the apartments are supplied exclusively with electric heating and cooking appliances.

General Engineering. — The foundations of all the buildings are supported upon concrete piles,

which vary in length from 5 to 14 meters, depending upon their location. The total number of piles installed is in excess of two thousand.

The framework of the generating room is of structural steel, those of the boiler and high tension switch houses are of reinforced concrete.

the Châlons factory of MM. Schneider et Compagnie. The travelling cranes were installed by the Union d'Electricité as soon as the frame-work was put in place and rivetted, and these cranes rendered the greatest service during the remainder of the construction.

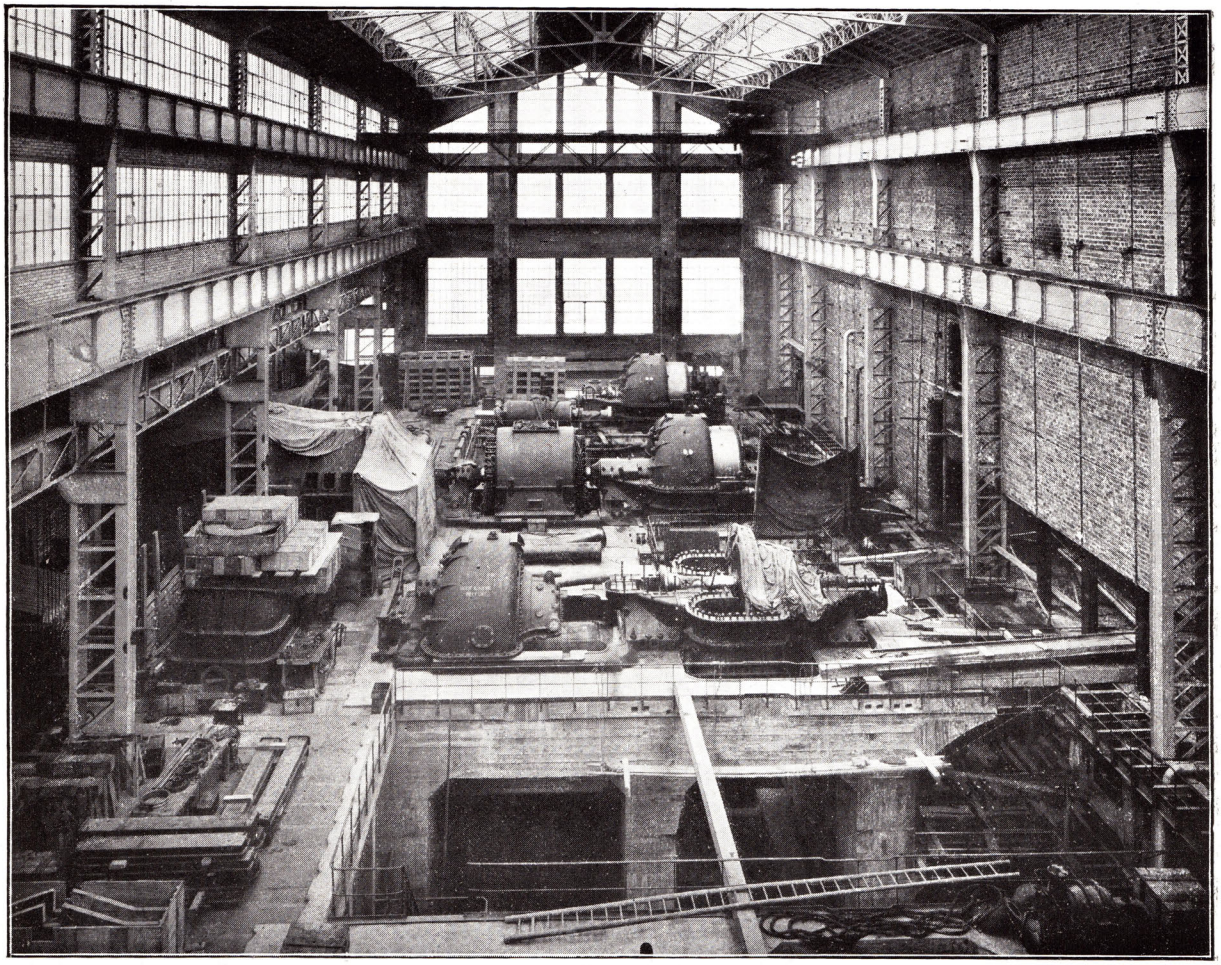


Fig. 50. — Interior View of the Main Generating Room (Northern End) taken after the starting of the tests on Unit No. 2.

The construction of the buildings was accomplished in a remarkably short time, which necessitated the employment of exceptionally powerful equipment. At a certain period five steam pile drivers, one excavator, two steam shovels, two locomotives, many electric winches and gasoline tractors were in operation simultaneously.

The total number of workmen employed, during several months, attained 1 300.

The structural steel shapes were constructed in

MM. Schneider et Compagnie also erected the buildings for the high and the low tension switch gear.

The remainder of the building construction was executed by the Société d'Entreprises (1) and upon this firm fell the responsibility for the major part of the work. This firm had many difficult engineering problems to solve, the principal ones being

(1) Société Générale d'Entreprises, 56, rue du Faubourg-Saint-Honoré, Paris.

those relating to the foundations for the generating room, the construction of the water intakes and the superstructure of the boiler house. In fact, in this latter building, the heavy loads to be carried by the supporting frames and the complicated lay-outs of the floors raised the most difficult technical questions. The Société Générale accomplished the task to the entire satisfaction of the Union d'Electricité.

Cost. — Due to the thorough study of all questions by the Société and due to the rigorous supervision of all expenditures, including the value of the grounds and that part of the financing charges attributable to the Generating Station (interest charges, cost of issuing and placing of the bonds, etc.), the cost of the station, based upon the first 200 000 kw. installed, will be slightly under 600 francs per installed kilowatt.

After the installation of units N° 6 and 7, the total power then being 280 000 kw., the cost per installed kilowatt will have decreased to 530 francs. This latter figure is based upon the supposition that the price of land, the cost of extensions, docks and labor remain the same as at present, and that the construction of the station, as it is actually built, will allow the placing of the 6 th unit without any addition to the present structure.

The goal, which the Société proposed to attain, was to construct a station at the pre-war price, regardless of the new and expensive apparatus decided upon.

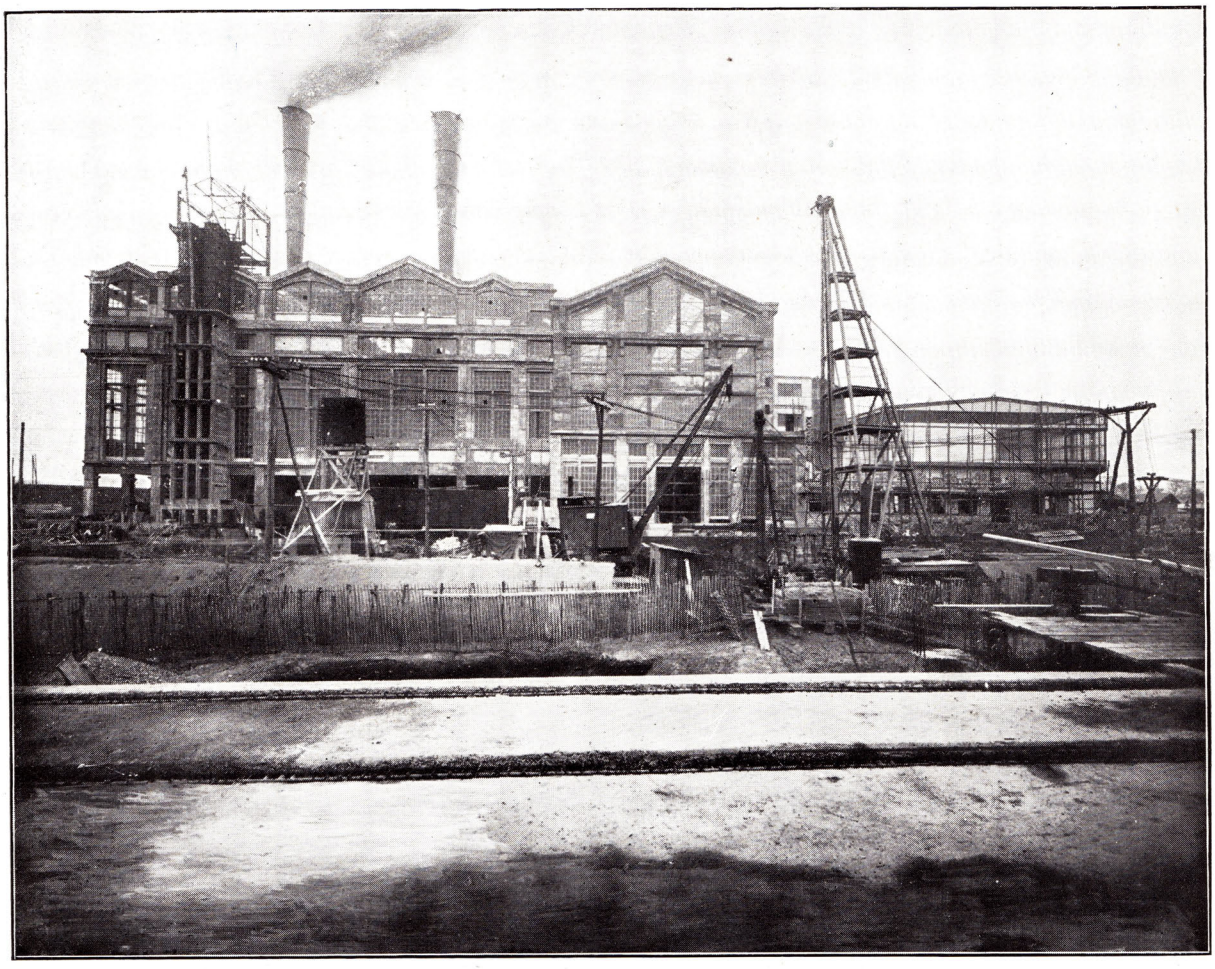


Fig. 51. — General View of the Station, Northern End (January 1922).

CHAPTER III

VARIOUS POWER PLANTS

I. — Vitry Power plant

The Vitry Power Plant has installed, at the present time, the following :

2 Vertical Curtis Turbines, each	9 000 kw.	25 cycle.
2 Horizontal Curtis Turbines, each	12 500 kw.	25 cycle.
1 Horizontal Turbine.....	6 000 kw.	50 cycle.

or a total of 49 000 Kw.

entirely at 50 cycles, and when so equipped will be used as an emergency and stand-by plant.

An annex will be built, in which will be installed a sub-station, equipped with synchronous condensers, and which will serve as the terminus of the high tension lines transporting power from the hydro-electric station at Center and also for the high tension lines from the Eguzon hydro-electric plant.

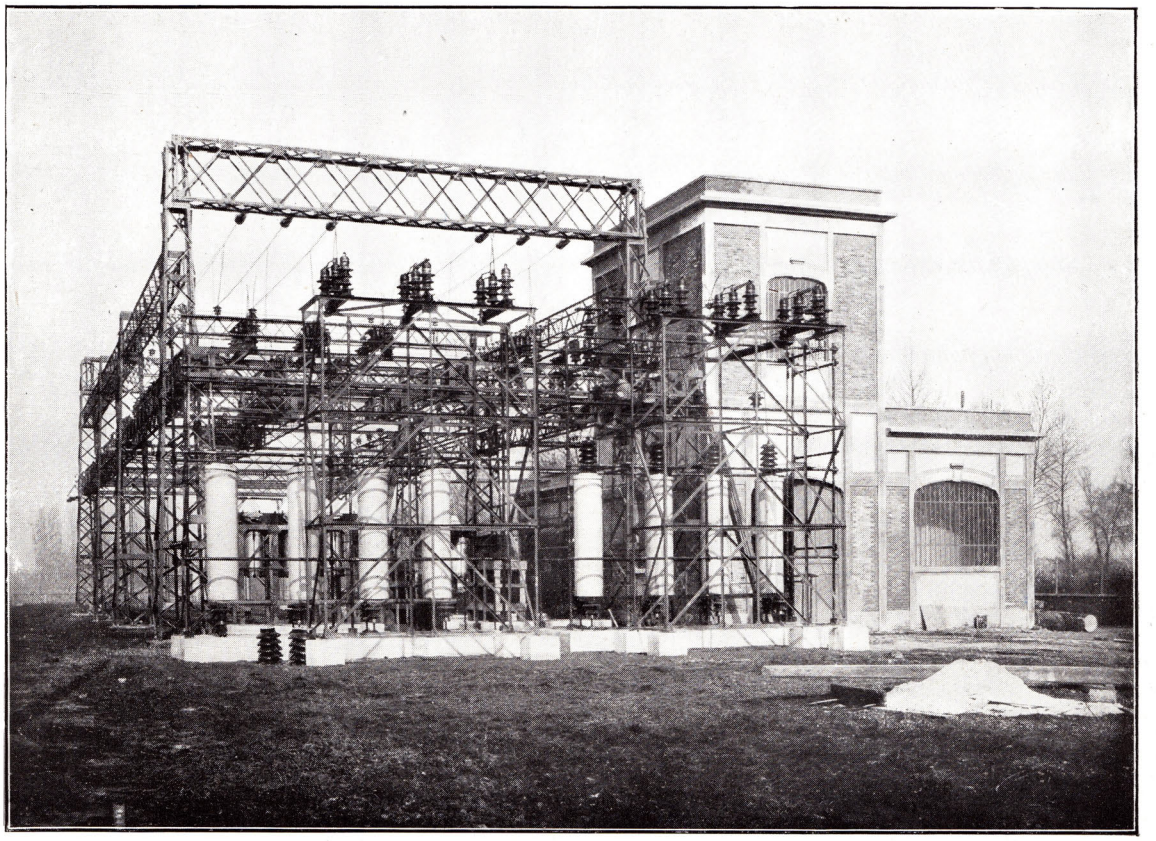


Fig. 52. — Outdoor Sub-Station at Creil — General View.

The station is now being changed. The vertical units are obsolete, and are being replaced by horizontal units of 15 000 kw., 3 000 rpm., 50 cycle, of which one unit is now being installed.

The two 12 500 kw. alternators will be rewound for operation at 50 cycles and rerated 15 000 kw.

After the above will have been completed, the station will have an installed capacity of 80 000 kw.

The Vitry station, which, when equipped, will show an interesting original lay-out, will be described in a separate circular.

II. — Nanterre and Issy-les-Moulineaux Power Plants

Each of the above plants is equipped with four 5 000 kw. turbo-generator units. The stations

were constructed in accordance to a contract with the State Railways (Chemins de Fer de l'Etat) and shall be purchased by the latter not later than the date of expiration of the present contract.

The financial charges of the above plant are covered by annual payments from the State Railways. These plants are therefore not included in the general program which the Union d'Electricité has proposed to carry out.

The Union has therefore decided to dispose of the buildings and equipment. The power plant of the Secteur de la Rive Gauche has already been sold. For the other plants it has been decided, according to the demand, to either sell the individual machinery or the entire plants for transportation to other parts of France or elsewhere.

Negotiations already undertaken for these sales

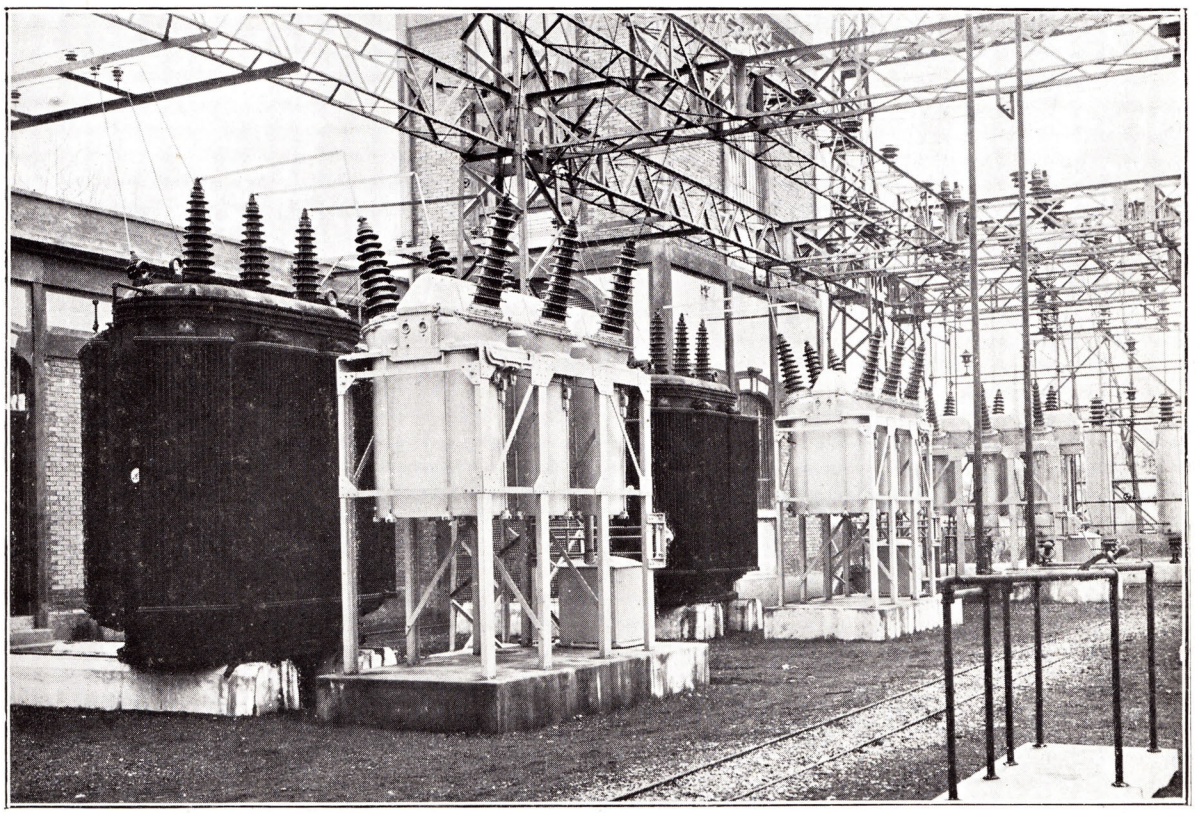


Fig. 53. — Outdoor Sub-Station at Creil — View of Transformer side.

III. — Other Plants

The other generating stations of the Union, Asnières, Puteaux, Billancourt and Alfortville, will be put out of commission, regardless of the fact that their material equipment is in excellent condition and their economy is compatible with the size of installed units.

It is only because the concentration of very large power at Gennevilliers and the stand-by station at Vitry permits the realization of greater economy, that the Union decided to no longer operate the small power stations.

by the « Service Special des Ventes de l'Union d'Electricité » have already produced very interesting propositions.

IV. — Sub-Stations

The installation of the sub-stations has been made the subject of extensive investigations. This question, itself, has such wide interest that it will be made the subject of a separate paper in which also will be described in detail the transmission lines, both underground and overhead.

CHAPTER IV

SUMMARY

Considering the power already decided upon, there will be installed and operated the following power plants.

Gennevilliers	320 000	Kw.
Vitry.....	80 000	—
Nanterre	20 000	—
Issy-les-Moulineaux ..	20 000	—

The Union d'Electricité will, therefore, at the end of a two or three year period, have a total installed capacity in excess of 400 000 Kw.

In publishing this paper, necessarily brief, and in which a subject, too vast for such a small effort, could only be slightly touched, we had two ends in view. We hoped to be useful to our colleagues in bringing to their attention the advantages which the centralization of exceptional large power can produce, and to submit for their approval one of the many solutions, which a parallel can bring forth.

We also wanted to demonstrate by a work already accomplished, how much in our country, which has so often and so lightly been considered as imbued with peculiarism, the idea of groupment and common organization have progressed. In this respect, we believe that no other country, no other capital, has yet given an example of such a varied association of interests, so efficaciously grouped and of a combination so rapidly constituted and of a program carried out so vigorously under particularly difficult conditions.

It is extremely comforting to relate the foresight displayed by the various sectors, the good-will of French industrials, their enterprising initiative, their sense of progress, their skill and devoted collaboration, which were so generously given to the Union and which have been the main factors of its success.

It is but fair to add that, in spite of having been continuously overworked during two years, the entire personnel of the Union, heads of Departments, engineers, draughtsmen, foremen and workmen, have contributed in the common aim with a real feeling of devotion and solidarity, with a technical intelligence, and an ambition to accomplish, which would have rendered any task easy. They have shown what could be expected, in the Industrial World, from the inborn qualities of one of the most industrious races in the World.

In drawing to a close, it is a particularly pleasant duty for me to take this opportunity of thanking the entire personnel of the Union d'Electricité, for the constant devotedness they have unceasingly displayed during the whole period of conception and construction.

Mr. Gustave MERCIER, ingénieur en chef des Ponts et Chaussées, an engineer of exceptional experience, in charge of the civil engineering work.

Mr. ARRIGHI DE CASANOVA, ingénieur en chef de la Marine, Chief Engineer of the Union d'Electricité, in charge of the investigation and installation of the mechanical engineering work, which he handled with exceptional competence.

Mr. COUFFON, ingénieur des Arts et Manufactures, Chief Electrical Engineer of the Union d'Electricité, who played an important part in the investigation and the satisfactory solution of the various problems connected with the installation comprising the distribution, the switching and the power plant itself, etc.

We also wish to especially thank Mr. BODMER, manager of the construction work; Mr. RAUBER, future manager of the Gennevilliers plant; Mr. MEUNIER, manager of the Commercial Service; Mr. CHALESSIN, director of the Service Administrative ; Mr. Henri PETSCHE, general Secretary; Mr. BERHAUT, and all the personnel : engineers, foremen and workmen of all class and order.

ERNEST MERCIER.

Board of Directors

of the Union d'Électricité

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Special Plans

(at the end of the book.)

Plan I. — Section of the Station (section parallel to the Seine).

Plan II. — Section of the Station (section perpendicular to the Seine).Water intake and Main Generating room.

Plan III. — Section of the Station (section perpendicular to the Seine). Boiler House.

Plan IV. — Lay-out of the Main Generating room.

Plan V. — Mechanical handling of coal.

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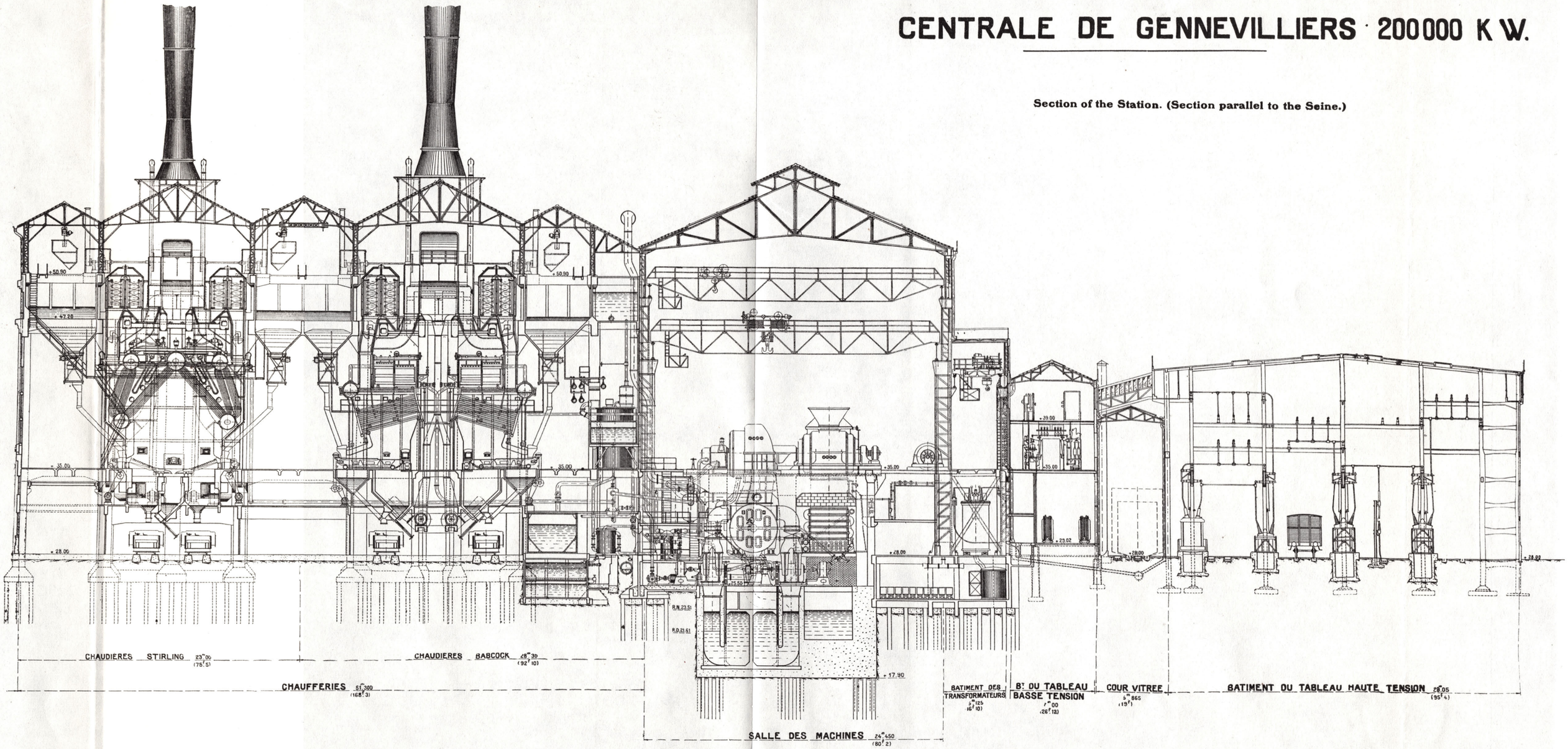
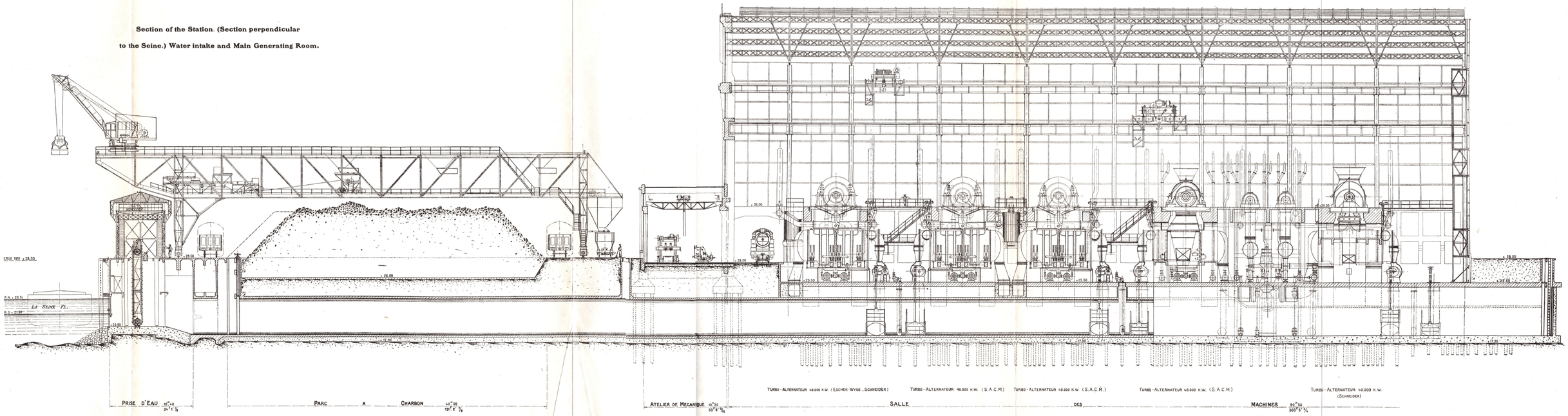
CENTRALE DE GENNEVILLIERS · 200000 K W.

Section of the Station. (Section parallel to the Seine.)



CENTRALE DE GENNEVILLIERS 200 000 K.W.

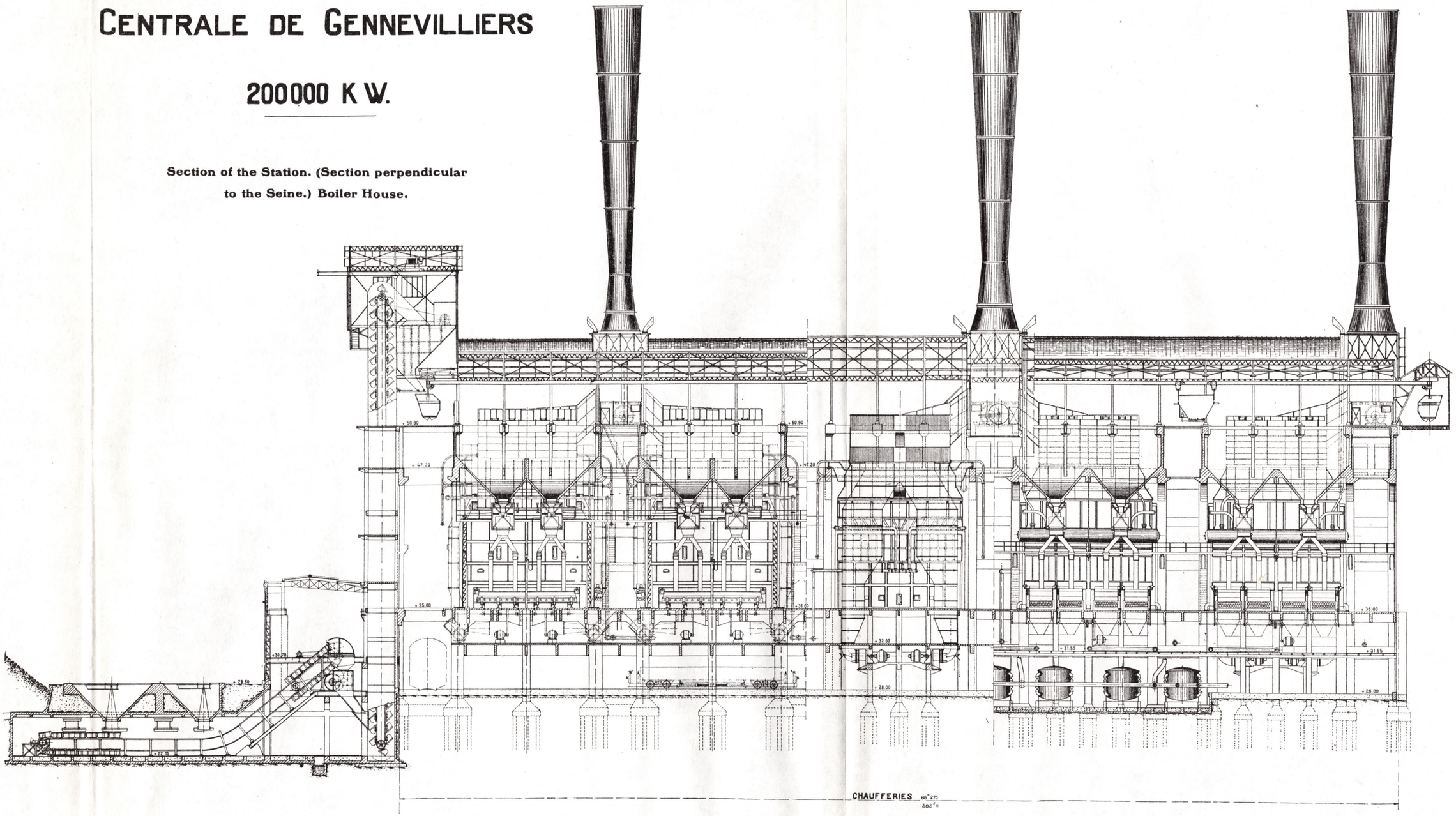
Section of the Station. (Section perpendicular to the Seine.) Water intake and Main Generating Room.

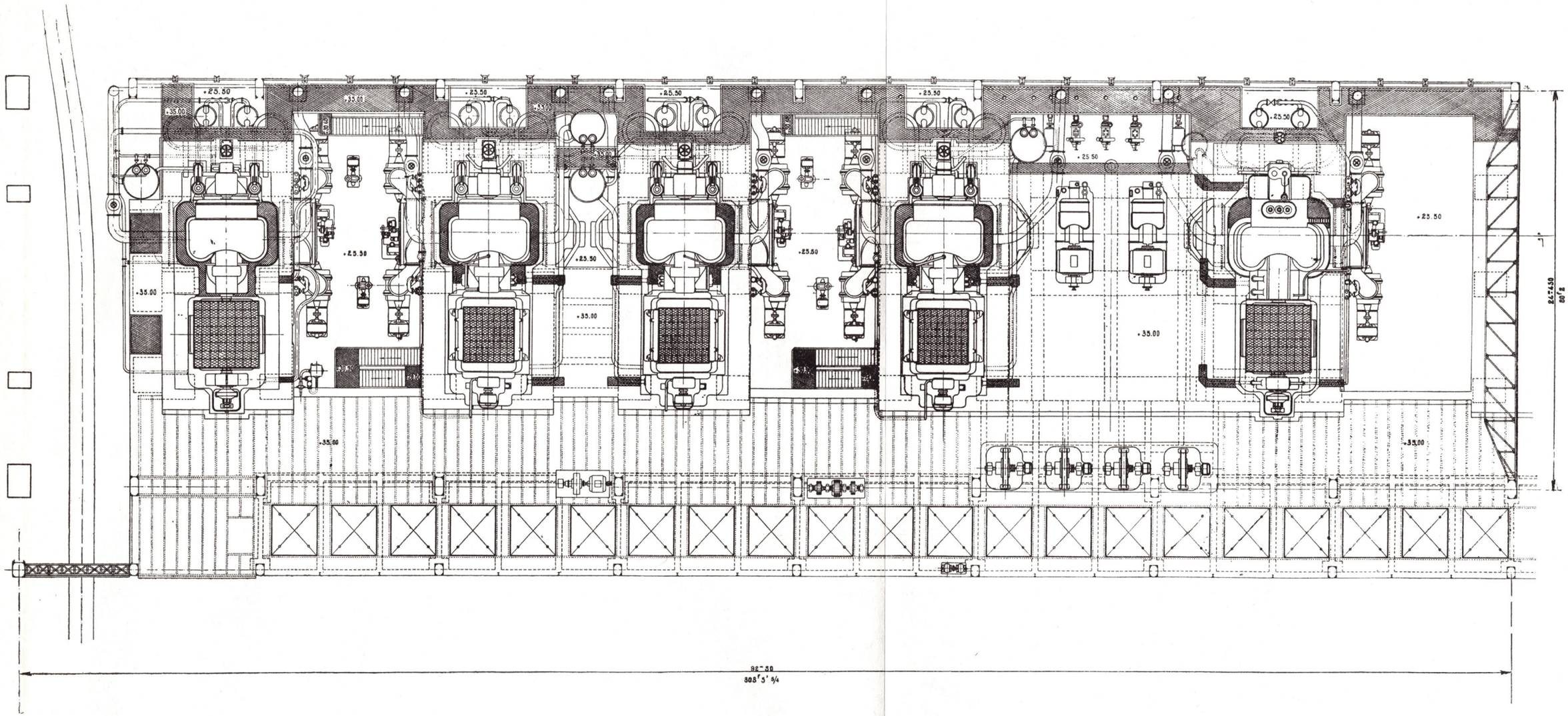


CENTRALE DE GENNEVILLIERS

200000 K W.

Section of the Station. (Section perpendicular to the Seine.) Boiler House.



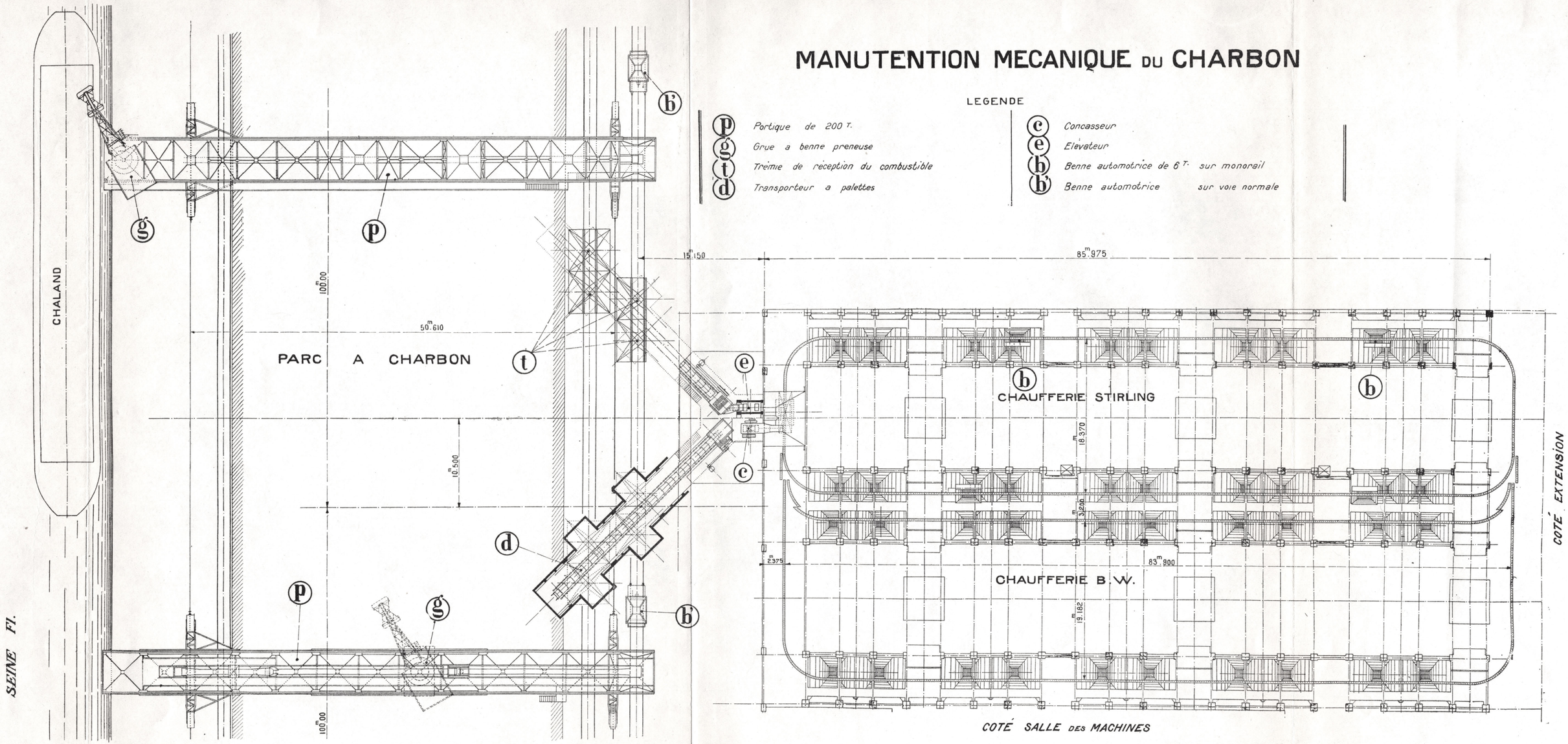


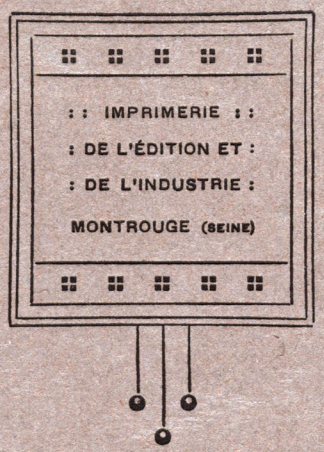
Lay-out of the Main Generating Room.

MANUTENTION MECANIQUE DU CHARBON

LEGENDE

- (p) Portique de 200 T.
- (g) Grue a benne preneuse
- (t) Treimie de réception du combustible
- (d) Transporteur a palettes
- (c) Concasseur
- (e) Elevateur
- (b) Benne automotrice de 6 T. sur monorail
- (b') Benne automotrice sur voie normale

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